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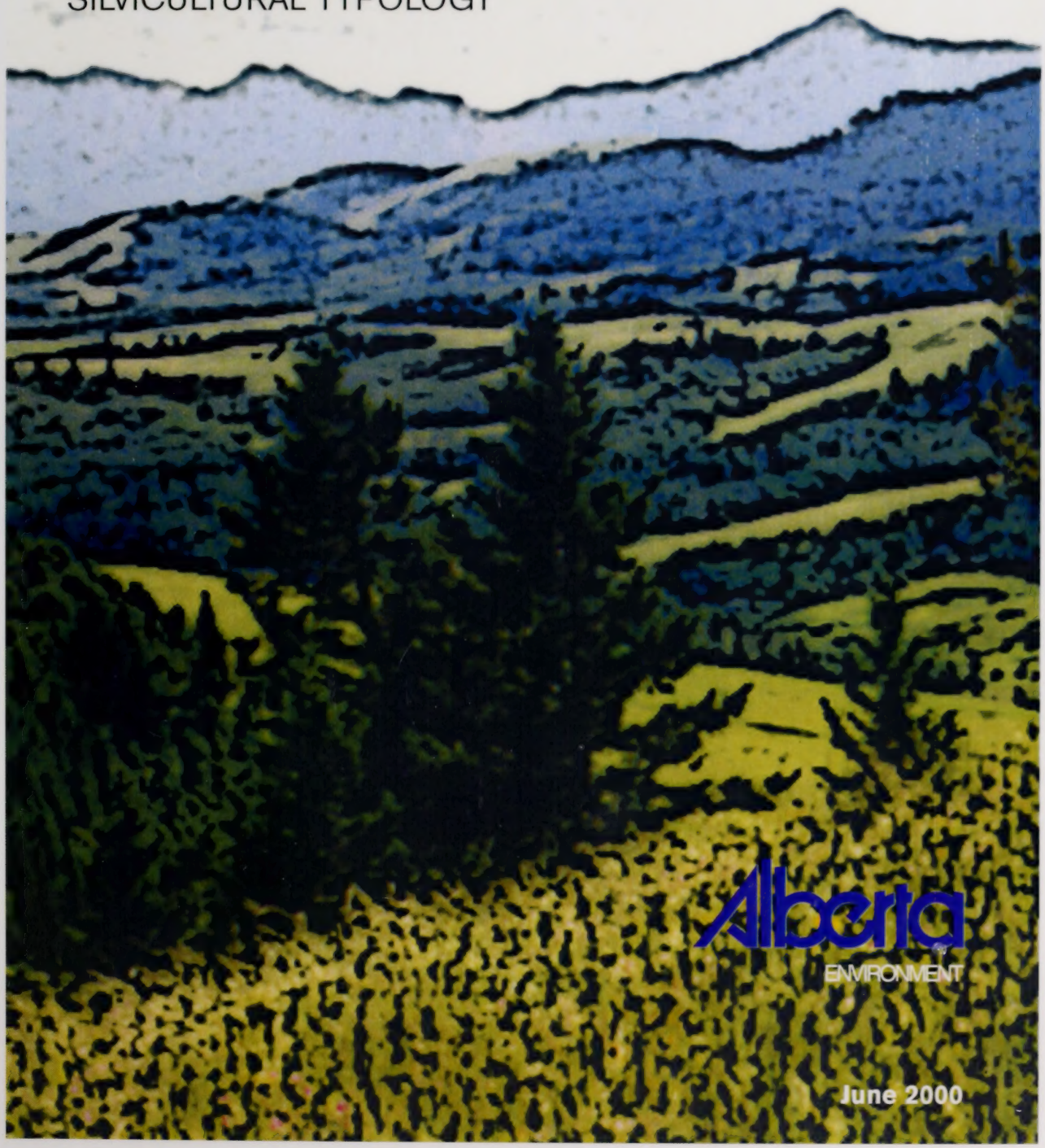
The Southern Rockies Landscape Planning Pilot Study

SILVICULTURAL TYPOLOGY



Alberta
ENVIRONMENT

June 2000

NOTE:
Every effort has been made to ensure the accuracy of the information in this report. Any opinions expressed are those of the authors and do not necessarily reflect the position of Alberta Environment.

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1. Introduction

The purpose of this document is to provide forest managers with an appropriate set of silvicultural options, treatments and extraction methods with which to carry out forestry practices within the managed forests of southwestern Alberta. Specifically, this document describes a typology of silvicultural options that may be suitable within the study area of the Southern Rockies Landscape Planning Pilot Project (refer to Figures 1 and 2). The descriptions are linked, where possible, to the ecological classification system and the pre-harvest assessment and silvicultural prescription methods which have been developed for Alberta.

The typology provides a range of silvicultural options with which planners, foresters and wildlife managers may meet their specific management objectives. This portion of the Southern Rockies Landscape Planning Project focuses on the silvicultural tools for achieving landscape and forest structural objectives and not the method of determining those objectives. The document also provides a general explanation of the potential forestry practices. It is not meant to give detailed silvicultural prescriptions but, rather, to provide types of treatments and the rationale for selecting them. A broad range of silvicultural systems, harvesting methods and extraction techniques which may apply to the management of the southeast slopes have been described as management options. Potential applications for each of these have been provided with the intention that they are to be used in conjunction with professional judgement and field experience in the development of site-specific, management prescriptions.

The type of silvicultural treatment that is selected may have a profound effect on the successional trajectory of individual stands as well as the future biological productivity of the site. Visual quality, hydrological process, erosion, specific wildlife habitat and business efficiency may also be heavily impacted by silvicultural treatments. In aggregate, the broad scale application of the typology will affect the structure, pattern and processes of the future forest landscape. This is an example of processes operating at a fine scale (e.g., harvesting and treatment at the stand level) and having an influence at a much broader scale (e.g., regional connectivity and biodiversity). Silviculturists are stand level managers who manipulate species composition, stem quality and vertical and horizontal structure. It is the manipulation of stand structure that offers the strongest link between strategic level plans and field operations. As harvesting and regeneration treatments have cross scale implications, the finer scale of silvicultural procedures is examined within the Southern Rockies Landscape Planning Pilot Project.

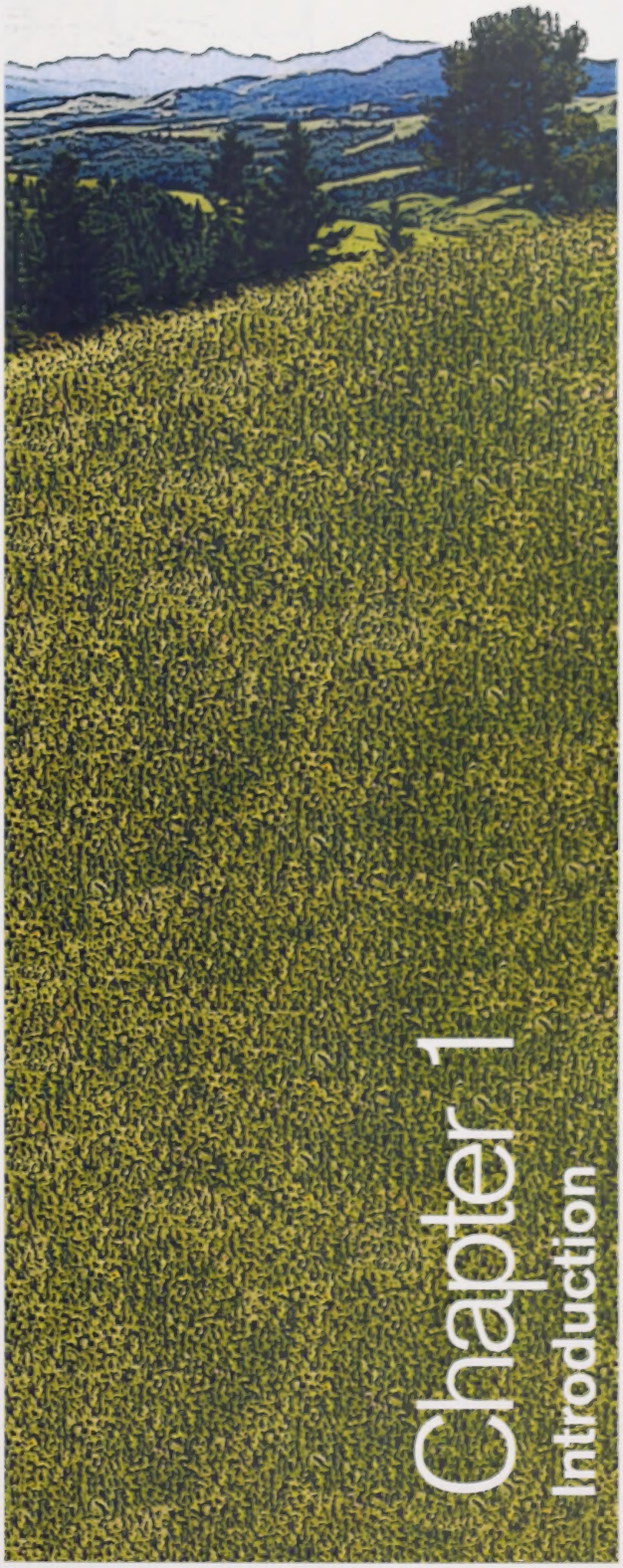


Figure 1. Study Area Provincial Context

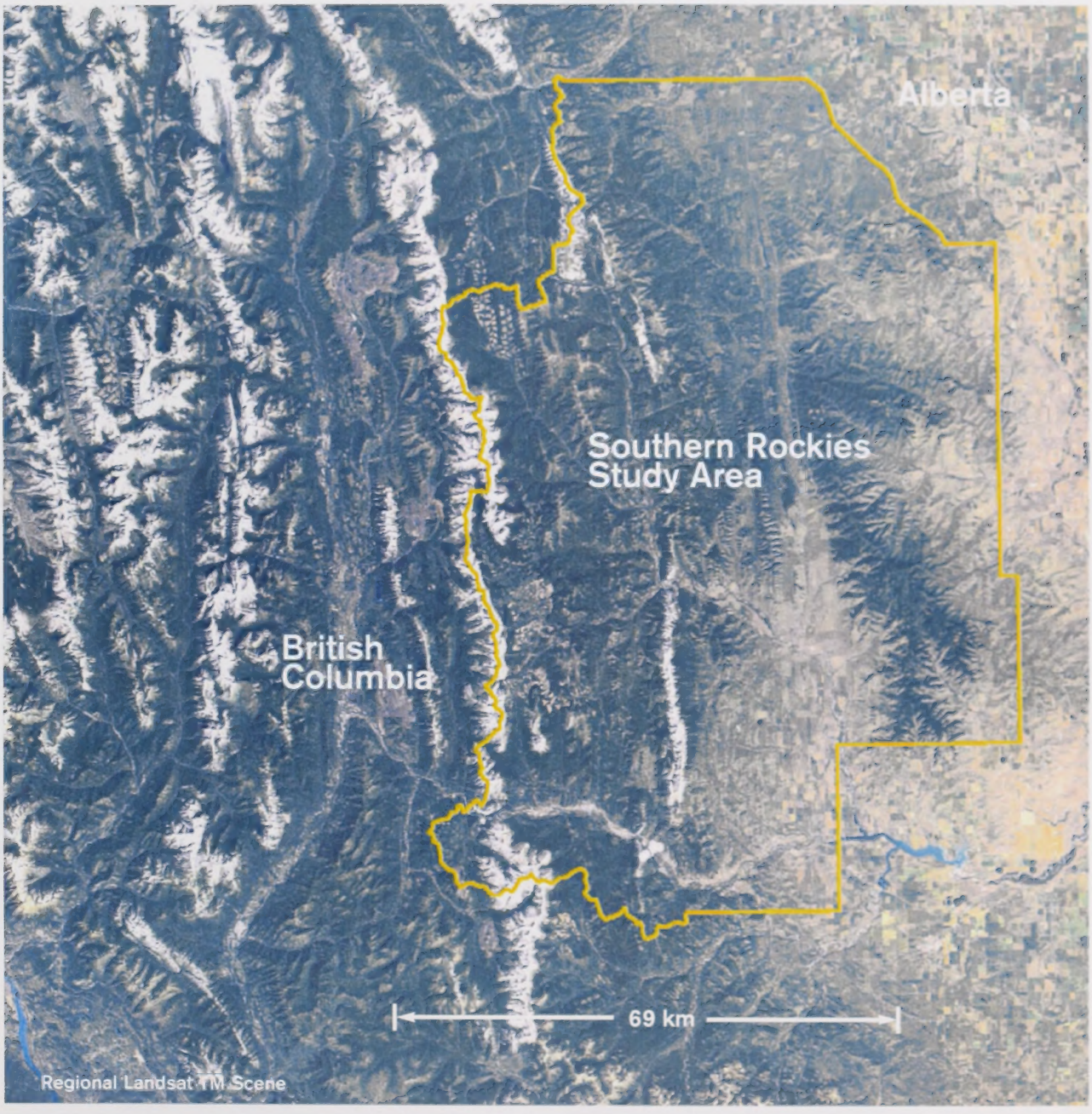


Figure 2. Study Area Regional Context

Figure 3. Cutblocks in the Study Area

2. Silvicultural Systems: Concepts and Terms

In order to achieve desired landscape pattern and stand structural objectives, forest managers have many silvicultural systems to choose from. Silvicultural systems, as the integrator of stand structure and stand level treatments, can be used to ensure that objectives are met over the life of the stand (rotation). Given the complexity of forest ecosystems, land use patterns and land management objectives, no one silvicultural system can achieve all objectives. The following descriptions are presented as management options and represent a wide range of silvicultural systems, extraction methods and treatments that may be useful to forest managers in achieving the desired landscape patch type and stand structure.

Some definitions are required:

- Silviculture is the theory and practice of controlling forest establishment, structure, composition and growth (Spurr and Barnes, 1980, p. 687).

- A silvicultural system may be defined as the process by which crops constituting a forest are tended, removed and replaced by new crops, resulting in the production of stands of distinctive form (Matthews, 1994, p. 3).

- A silvicultural system is... the art and science of managing forest vegetation by controlling the establishment, growth, composition, quality and structure of forest stands to meet specific forest management objectives (Matthews, 1994, Smith, 1986).

- A silvicultural system is a planned program of silviculture treatments, designed to meet specific stand structural objectives that have been formulated to meet specific forest resource management objectives (Bancroft et. al., 1992).

Treatments are planned over the life of the stand and will include short- and long-term stand structures. The silviculturist translates broader management objectives into stand structural objectives and then formulates a program of treatment that will promote the desired stand structure(s).

A harvesting (extraction) method is the process by which the cutting is completed. This includes the falling, skidding, landing, loading and hauling of wood fibre from the logging site to the mill. Consideration must also include limbing, topping and debris disposal.

The scope of specific silvicultural treatments falls within two categories:

1. regeneration method (reproduction method) refers to treatment of the stand and site during the establishment of regeneration; and
2. stand tending treatment refers to any stand treatment, at times other than regeneration, during the rotation.

2.1. FOREST STRUCTURE

Forest and stand structural objectives are the departure point for silvicultural prescriptions. Specific components of stand structural objectives include:

- species composition;
- age class;
- stocking pattern and spatial distribution; and
- special structural elements including coarse woody debris, large diameter trees and cavity nesting habitat.

A forest stand consists of varying degrees of both vertical and horizontal structure. Tall stands that are well stratified with a number of layers will generally support a more diverse biota than a simple, single layer stand. To manage a stand for a diverse vertical structure (*if* management objectives make this desirable), the forest manager may employ types of uneven-aged stand management that produce uneven-height forests. Silvicultural treatments such as thinning, pruning and fertilizing may help to initiate the development of lower level strata in even-aged stands.

2.1.1. VERTICAL STAND STRUCTURE

Vertical stand structure refers to the aerial, surface and subsurface layers within a forest stand. There may be several layers within each stand, each of which functions differently, all of which combine and contribute to the overall function of the stand. The simplest forest stand structure within the study area would be an even-aged, fire origin pine stand. One of the most complex forest stand structures within the study area would be an uneven-aged, Engelmann spruce, subalpine fir, climax stand (refer to Figure 4).

2.1.2. HORIZONTAL STAND STRUCTURE

Horizontal stand structure refers to the diversity of structure across any given forest stand (refer to Figure 5). A forest stand is usually described in terms of density, height, overstory and understory tree species composition. Forest inventory data is compiled to yield information on stand volume (m^3/ha), basal area (m^2/ha), stems per hectare and commercialism of potential wood products. Other attributes that are important to horizontal stand structure are the distribution of snags and downed woody debris. Horizontal stand structure changes from one forest cover type to the next on a landscape scale (refer to Figure 6). The transition from one stand to the next may be abrupt or it may be an extended transition. The structure (shape, width and species) and composition of the edge of the patch should also be considered.

Figure 4. Vertical Stand Structure

C23Se6Fa3Pl1/A5FaSe (Engelmann spruce, subalpine fir, climax stand)

Horizontal structure changes within the stand type.

Figure 5. Horizontal Stand Structure C23Se6Fa3Pl1/A5FaSe (mature Engelmann spruce, subalpine fir stand)

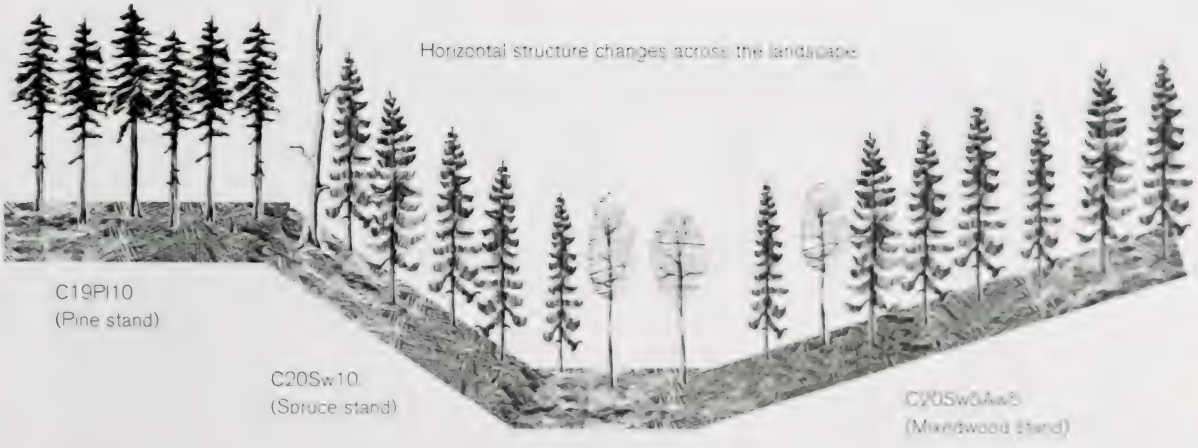


Figure 6. Horizontal Structure on a Broader Scale

2.2. EVEN-AGED SILVICULTURAL SYSTEMS

An even-aged silvicultural system will produce relatively even-aged stands. Even-aged systems can have a variety of internal stand structures in the short-term. In the long-term, even-aged systems have generally similar age and size structures, although this may be modified by retention of structure within the cutblock, heterogeneous cutting patterns or variable species composition (BC Environment, 1995) (refer to Figure 7).

Characteristics of an even-aged stand include

- a relatively narrow range of tree ages (the range in ages does not exceed 20% of the length of the rotation – usually ages are within the same 20-year age class interval)
- generally favours shade-intolerant, seral tree species such as lodgepole pine and aspen
- often develops after a catastrophic stand replacing fire event
- as the stand approaches rotation age, a relatively uniform stand structure and even canopy develops

The primary advantage of an even-aged system is the uniform stand conditions which facilitate mechanized harvest and reduced operating costs (Strong and Carnell et. al., 1996, pg. 66). It (generally) involves less road construction and maintenance and fewer stand entries.

2.2.1. CLEARCUT

The clearcut is defined as an area of forest land from which all merchantable trees have been removed in a single stand entry (refer to Figure 8). The complete clearcut sequence in an area may consist of two or more passes. The mature, even-aged stand is completely removed in the first pass. Under existing ground rules, the second cut in the adjacent stand occurs only when the regeneration in the first cut area has reached a minimum height of 3 meters. Variations of the clearcut system include block, strip and patch clearcutting.

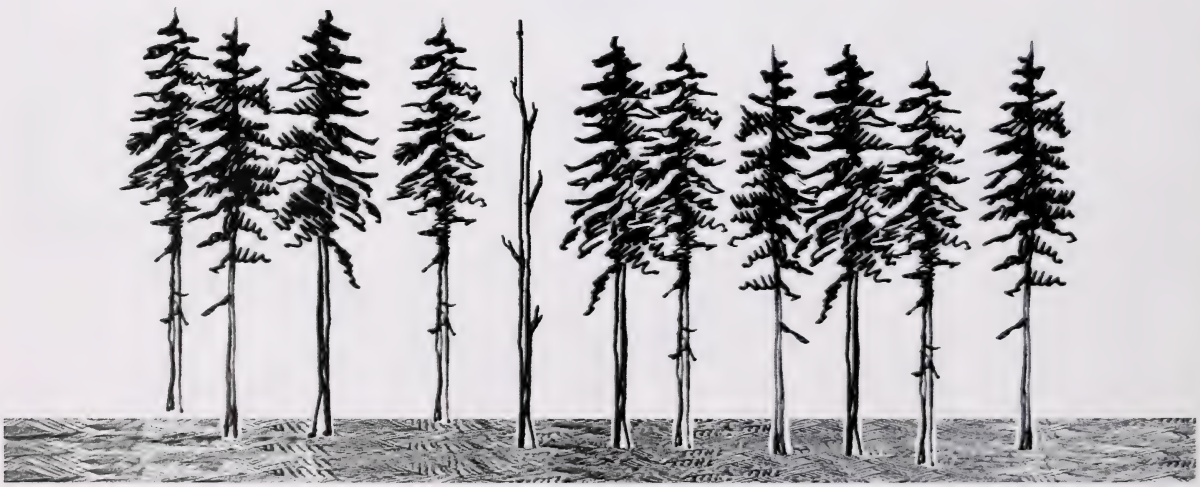
Reforestation can be achieved naturally from:

- seed from adjacent forest stands, disseminated over the cutting area;
- trees removed during the harvesting operation (with a variety of treatment options); or
- advanced regeneration protected on site during the harvesting operation.

Reforestation can also be achieved artificially from:

- planted tree seedlings or sown seed (Strong and Carnell et. al., 1996).

Uniform age and height



Fire-origin, lodgepole pine stand – developed as a result of rapid establishment of pine seedlings after a hot, stand-replacing fire.
(Eg: C–density, 20 meter tall lodgepole pine stand)

Figure 7. Even-Aged Forest

Characteristics and potential impacts of clearcuts

- all merchantable trees are removed (based on a given utilization standard)
- promotes shade-intolerant early to mid seral species
- microsite shelter is a function of the amount and distribution of downed woody debris left on site after harvesting and scarification (there is no overstory to provide protection)
- potential reduction of length of roads and number of water crossings because larger contiguous cutblocks require less roading
- higher erosion potential from the scarification techniques often associated with clearcutting (dependent upon soil texture, moisture and percent slope) – the clear felling itself is generally not the most significant cause of erosion
- visual impact may be highly dependent upon the visual absorption capacity of the surrounding residual area and the actual block configuration

Advantages of the clearcut system

- a simplified system which facilitates mechanized harvest, site preparation, reforestation and stand tending
- allows for the application of the most cost effective harvest methods – however, overall costs may not be the lowest if site preparation and artificial reforestation are required
- useful for converting to a shade-intolerant seral tree species
- results in an even-aged stand which facilitates simplified operations into the next rotation
- may mimic certain aspects of stand replacing fires
- where artificial reforestation is prescribed, there is an opportunity to:
  - capture the effects of tree improvement programs
  - control species composition
  - control stocking pattern and numbers

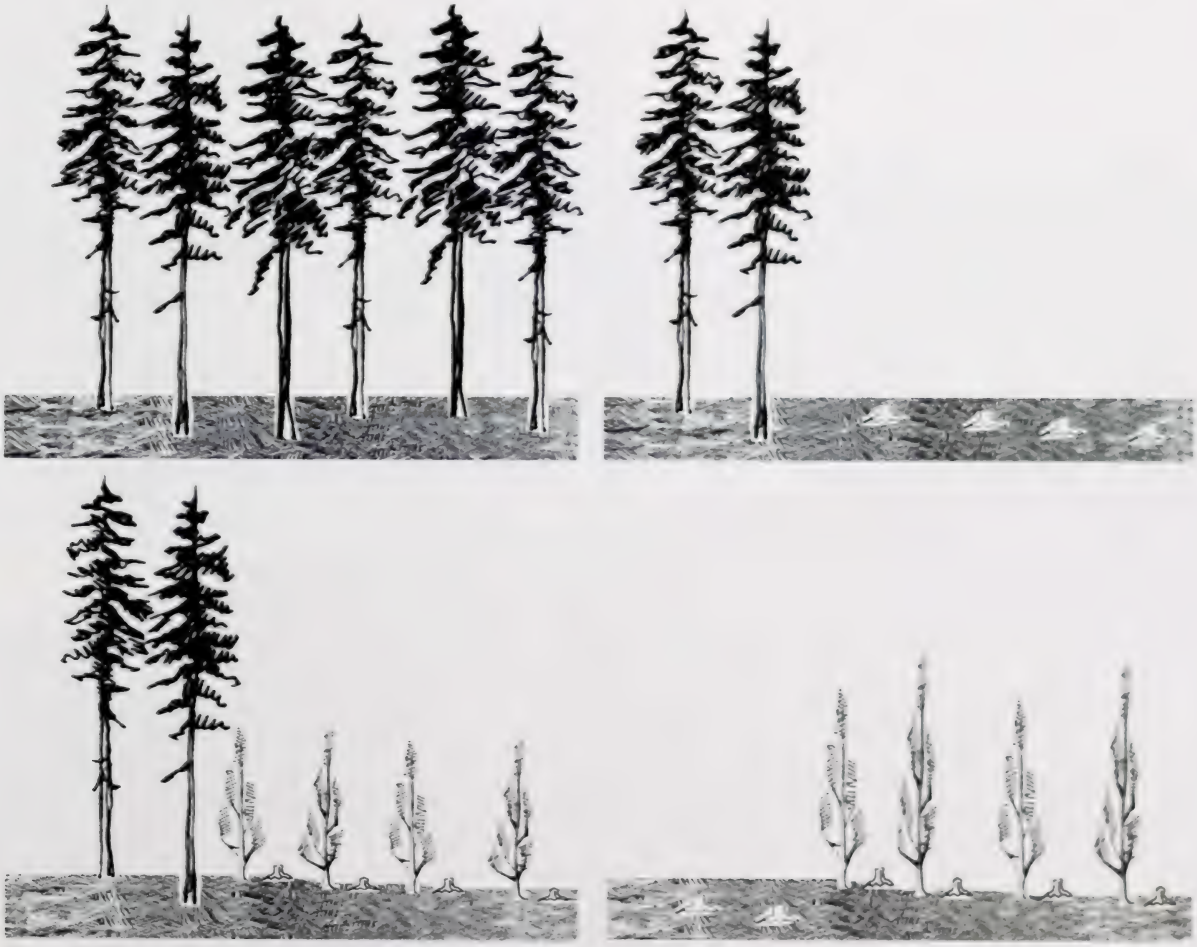


Figure 8. Clearcut System

Disadvantages of the clearcut system

- site disturbance is high and provides increased potential for erosion and rapid run off
- aesthetics may be poor until regeneration is well established
- may be associated with poor public perception due, in part, to historical cutting practices
- competition created by grasses, forbs, shrubs and unwanted trees may restrict the regeneration of desired crop trees

Applications for the clearcut system

- coniferous or deciduous stands that are over-mature and which have a high amount of dead or dying trees caused by forest insects, disease or blow down
- sanitation operation, where it is important to remove all potential host material in order to reduce the impact of the insect or disease problem
- on sites where an even-aged stand of shade-intolerant species is desired
- on sites where major species conversion is desired
- the clearcut may be the only silvicultural system suitable for perpetuating even-aged pine stands that contain a component of aspen
- a progressive clearcut may be useful in creating large contiguous openings that mimic large stand replacing fires – this may be conducted in one large operation or a number of smaller operations that progress across the operating area (overall configuration of clearcuts is addressed elsewhere)

2.2.2. PATCH CUT

The patch cut is a miniature version of the clearcut. The openings created under this system are less than 1 hectare in size (BC Environment, 1995). Silviculturally, these openings will create an exposed microsite which will facilitate the establishment of shade-intolerant, seral pine types (refer to Figure 9).

Characteristics of the patch cut system

- this system differs from clearcut in extent only – by definition, patch cuts are less than 1 hectare in size
- this system differs from group selection because selection groups or strips are not more than twice the height of adjacent mature trees (Smith, 1986) and are generally less than 1/4 hectare

Figure 9. Patch Cut

- less conspicuous in the landscape (depending on size, shape, position and residual structure within the block)
- higher edge to interior ratio (undulating edges)
- increased edge provides a higher potential for natural regeneration from adjacent stands (ingress)
- reduced block size results in increased benefit for edge wildlife species
- high number of small patches may create fragmentation after 50% of the area is cut

Impacts of the patch cut system

- may have a relatively high visual preference
- increased road and trail networks to access smaller blocks may increase both erosion and habitat fragmentation
- site impact is generally the same as for clearcut except the patch area is much smaller

Advantages of the patch cut system

- may have a higher visual preference and positive public perception
- may create an opportunity to promote small-scale wood operations (small business)
- a low to moderate degree of patch cutting may create a better interspersion of forest cover and openings for some wildlife species

Disadvantages of the patch system

- increased road and water crossings to access a higher number of smaller blocks
- increased cost of site preparation and regeneration establishment over a high number of small blocks
- a high degree of patch cutting will fragment the landscape which may reduce its effectiveness as habitat for some interior species

Application of the patch system

- this system is useful in areas of high visual preference where an even-aged class structure is desired – small patches may be less conspicuous from critical view points
- small scale, low-impact horse logging operations using the patch cut system may be a viable way to promote forest management in sensitive areas

2.2.3. COPPICE

The coppice system is defined as a deciduous, even-aged silvicultural system for which the primary regeneration method of trees is vegetative sprouting of either suckers (originating from existing root systems of cut trees) or shoots (originating from the cut stump) (BC Environment, 1995). There are two variations of the coppice system, the simple and the compound.

1. The simple coppice system, where all merchantable trees within the cutblock are harvested during the dormant season, gives rise to an even-aged regenerating stand (refer to Figure 10).
2. In the compound coppice system or coppice with standards method, all of the merchantable trees in the cutblock are harvested while reserving a few of the better trees (standards) from each rotation. The standards are kept to grow into larger trees while successive crops of coppice sprouts grow up around them. New standards are recruited from each coppice crop to replace the standards removed in thinning or final harvest cuttings of the overstory (Smith, D., 1986). The end result is a coppice crop of suckers and sprouts in the understory with an uneven-aged overstory of larger trees of the same species (refer to Figure 11).

A simple aspen clearcut, during a winter operation, will provide sufficient light and heat during the next growing season to promote suckers and shoots. Often cut-overs quickly become overstocked with new saplings.

Figure 10. Simple Coppice System

Characteristics of the coppice system

- the system is designed only for those species that have the capability to regenerate vegetatively (primarily hardwoods such as aspen and poplar)
- promotes deciduous shade-intolerant, seral species (primarily aspen)
- there is no opportunity for genetic improvement from outside of the clone
- in the simple coppice system, microsite shelter is a function of the amount and distribution of downed woody debris left on site after harvesting
- in the compound coppice system, microsite shelter is provided by the uneven-aged overstory
- in the compound coppice system, roads remain in place longer to facilitate multiple stand entries
- deciduous regeneration quickly fills in to provide browse and hiding cover
- an even-aged stand is formed in the simple coppice method, as well as in the understory component of the compound coppice method
- the uneven-aged overstory created by the compound coppice method will have age classes that are multiples of the coppice rotation age, providing the opportunity to create a balanced, uneven-aged overstory (Smith, 1986)

Impacts of the coppice system

- site and soil impact may be reduced if system is restricted to winter operations
- erosion potential is generally reduced as sprouting helps to hold soil in place
- visual impact may be high (dependent on cutblock size, shape, position and residual structure)

Advantages of the coppice system

- cost effective in the short run
- no additional reforestation costs
- suckers and sprouts quickly provide browse and cover for ungulates
- coppice with standards generally receives a higher visual preference rating

Original Stand

A few years after the first coppice cut, selected standards remain on site.

A few years after the second coppice cut, 3 age classes are present.

The compound coppice system may create an uneven-aged stand by leaving standards from each coppice cutting. This example shows 3 30-year rotations of coppice cuttings. This ultimately creates a balanced, uneven-aged stand.

Figure 11. Compound Coppice System

Disadvantages of the coppice system

- simple coppice has a low visual preference

Applications for the coppice system

- the simple coppice system is useful for producing quick rotation of aspen pulp wood
- the compound coppice system may be useful in meeting timber supply objectives where both large and small diameter wood is needed from the same land base (fuel wood/pulpwood or pulpwood/sawlog)
- the compound coppice system may be useful for meeting biodiversity, wildlife habitat and/or visual preference objectives

2.2.4. SEED TREE

The seed tree method is defined as a silvicultural system in which selected trees or groups of trees are left standing after the initial harvest to provide a seed source for natural regeneration. After natural regeneration has been achieved to standard, the high-value seed trees may be removed or some may be retained to help achieve stand structural objectives (refer to Figure 12).

A preparatory cut or intermediate cut (low thinning) may be done several years prior to the regeneration cut in order to promote wind firmness and the health and vigour of the remaining trees. The primary objective during this operation is to leave the best quality trees on site in order to promote a vigorous stand with the highest possible genetic quality ultimately benefiting long-term site management. Variations in the seed tree system include: uniform (evenly spaced individual trees), group (small groups of residual trees) and strip (alternating strips of residual trees) systems. The chief distinction from shelterwood cutting is that the remaining crown cover (seed trees) is not enough to make the cutting area microclimatically different from the broad, open, clearcut area that is created by the seed tree regeneration cut (Smith D. 1986, p. 397).

Primary considerations in selecting a seed tree are:

- wind firmness (large crowns = large root systems) (a wide tapering bole increases wind firmness);
- seed production (large deep crown) (high volume of healthy cones); and
- plus trees (desired shape, health, vigour and species considering local insects and diseases).

Characteristics of the seed tree system

- most merchantable trees are harvested during the initial harvest
- significant opportunity for genetic improvement
- seed trees left standing for either the short- or long-term
- favours early seral species (small amount of shade provided)

Potential impacts of the seed tree system

- high erosion potential (dependent upon soil texture, moisture and percent slope)

Advantages of the seed tree system

- maintains local gene pool
- opportunity for genetic improvement for the new stand through the selection of superior seed trees
- promotes new stand vigour and health — insect and disease resistance
- avoid the cost of artificial regeneration
- seed trees can grow into valuable large diameter sawlogs or peeler logs if left through a second rotation
- seed trees left through a second rotation may help achieve stand structural and biological diversity objectives

Disadvantages of the seed tree system

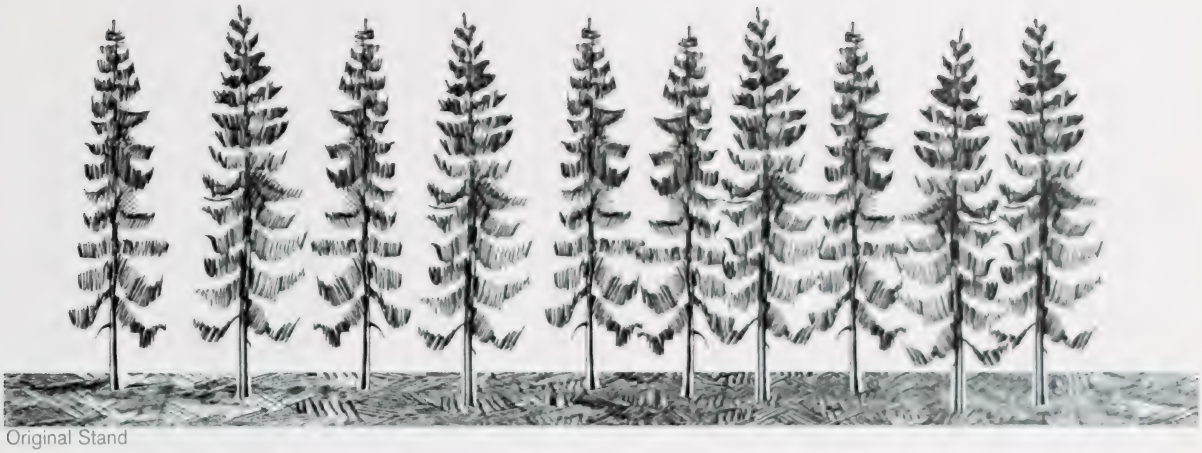
- blow down potential of seed trees
- increased cost of harvesting seed trees after the initial regeneration cut
- possible damage to regeneration during removal of seed trees
- visual preference may be low

Application for the seed tree system

- where natural regeneration is desired
- where genetic improvement is desired
- where an even-aged crop is desired to facilitate future harvesting operations
- to Douglas fir stands which are relatively wind firm. Seed tree systems may also provide for the maintenance of large Douglas fir veterans well beyond the stands regular rotation for structural and ecological purposes. Healthy, mature Douglas fir should be selected for recruitment as large veterans.
- the seed tree system may provide an opportunity to promote the natural seeding of white and Engelmann spruce in areas where good cone crops are sporadic as it is difficult to collect significant volumes of seed for reforestation efforts

Variations for the seed tree system

- Group Seed Tree — groups of trees are left throughout the cutblock in an even but patchy distribution
- Uniform Seed Tree — residual single trees are left scattered evenly throughout the cutblock



Original Stand

Seed trees remain on site until natural regeneration is established.

Good quality seed trees may be left individually or in small groups to provide a seed source for the establishment of natural regeneration. Once regeneration is established, the seed trees may or may not be removed.

Figure 12. Seed Tree System

2.2.5. SHELTERWOOD

The shelterwood system is defined as a silvicultural system in which mature trees are removed in a series of cuttings to produce an even-aged stand under the protection or shelter of the remaining trees (BC Environment, 1995).

Regeneration may be achieved naturally using the overstory as a natural seed source by planting the harvested area to a more desirable species composition or by protecting advanced regeneration. The different types of shelterwood systems include uniform, strip and group shelterwood which may be identified by the spatial arrangement of the leave trees through the different cuttings. Irregular, natural and nurse-tree shelterwood systems differ in the timing of understory release. Several different types of shelterwood methods are used. Each method involves two or three different kinds of cuttings applied in the following order (Smith, 1986):

- Preparatory cutting or intermediate cutting may be considered late in the rotation but several years prior to the regeneration cut in order to promote wind firmness, health and vigour of the leave trees (not always necessary).

- Regeneration cutting involves opening up enough vacant growing space in a single operation to allow the establishment of new regeneration. The timing of this cut should coincide with a good cone crop of the desired species.

- Overstory removal cutting gradually uncovers the new crop of trees while making the best use of the overstory's growth potential. There may be a need for one or two removal cuts depending on how much protection the understory needs and how well the overstory will respond in growth or volume increment.

- Final cutting is the last cut made on the site which completely uncovers the regeneration. The first removal cutting may actually be the final cutting.

Characteristics of the shelterwood systems

- favours the regeneration of shade tolerant or shade requiring species on south aspects and climax species on north aspects
- there is an opportunity for genetic improvement if the poorer quality trees are removed during the regeneration cut
- facilitates natural regeneration but artificial regeneration may also be prescribed

Potential impacts of the shelterwood system

- visual preference should be acceptable during the regeneration and removal cuts – the acceptability of the visual condition created by the cutblock after overstory removal will likely be reduced but will be influenced by the size, shape, position and residual structure of the cutblock

Advantages of the shelterwood system

- avoids the cost of artificial regeneration
- provides a seed source for an extended period of time
- the preparatory and regeneration cuts may promote an increase in growth and value of the residual trees
- provides an opportunity to promote mixedwood site management
- promotes genetic improvement
- provides seedlings with protection from frost, drought and wind
- maintains internal cutblock structure which functions as wildlife habitat for some species
- provides an opportunity for fuel management
- provides an opportunity to maintain high forest cover in the short-term and the irregular shelterwood system maintains high cover over the long-term

Disadvantages of the shelterwood system

- the number of stand entries increases the harvesting cost per cubic meter
- understory protection can be difficult and costly
- main access roads are open longer to facilitate multiple stand entries

Applications of shelterwood system

- for lodgepole pine sites where the cones are not closed or serotinous allowing for some seed dispersal. Shade provided by the retention of a lodgepole pine shelterwood may provide some shade for regeneration originating from slash cones and may also impose the types of variations in seedling height that mitigate overstocking (Smith, 1986).
- the shade tolerant Engelmann spruce, subalpine fir and Douglas fir may respond well to a shelterwood silvicultural system allowing for the management and maintenance of these for mid to late seral species
- the shelterwood system may be effective in the Montane forest region on dry, well-drained, south aspects when trying to regenerate Douglas fir. The partial shade provided by the residual Douglas fir would help to reduce moisture loss and reduce extremes of surface temperature which may promote more successful regeneration.
- this system provides an opportunity to manage a site for multiple resource objectives. While managing the stand for shade-tolerant mid to late seral species, a reasonable amount of fibre may be recovered while maintaining high forest cover and internal block structure for wildlife. Fuel loading may be modified to reduce the potential head fire intensity and crowning potential.
- in presently unmanaged aspen stands (specifically within the study area), the nurse-tree shelterwood system may provide an opportunity to establish shade-tolerant conifers such as white spruce or Douglas fir by under planting those stands

Original Subalpine Spruce/Fir Stand

Preparatory Cut

Regeneration Cut

Final Cut

The uniform shelterwood system provides shade for the natural establishment of shade-tolerant spruce and fir.

Figure 13. Uniform Shelterwood System

2.2.5.1. UNIFORM SHELTERWOOD SYSTEM

The uniform shelterwood system involves a regeneration cut to provide an even distribution of leave trees in sufficient number to provide the appropriate microsite conditions for the new crop of trees. Subsequent removal and final cuts are conducted when the established regeneration no longer requires overstory protection (refer to Figure 13).

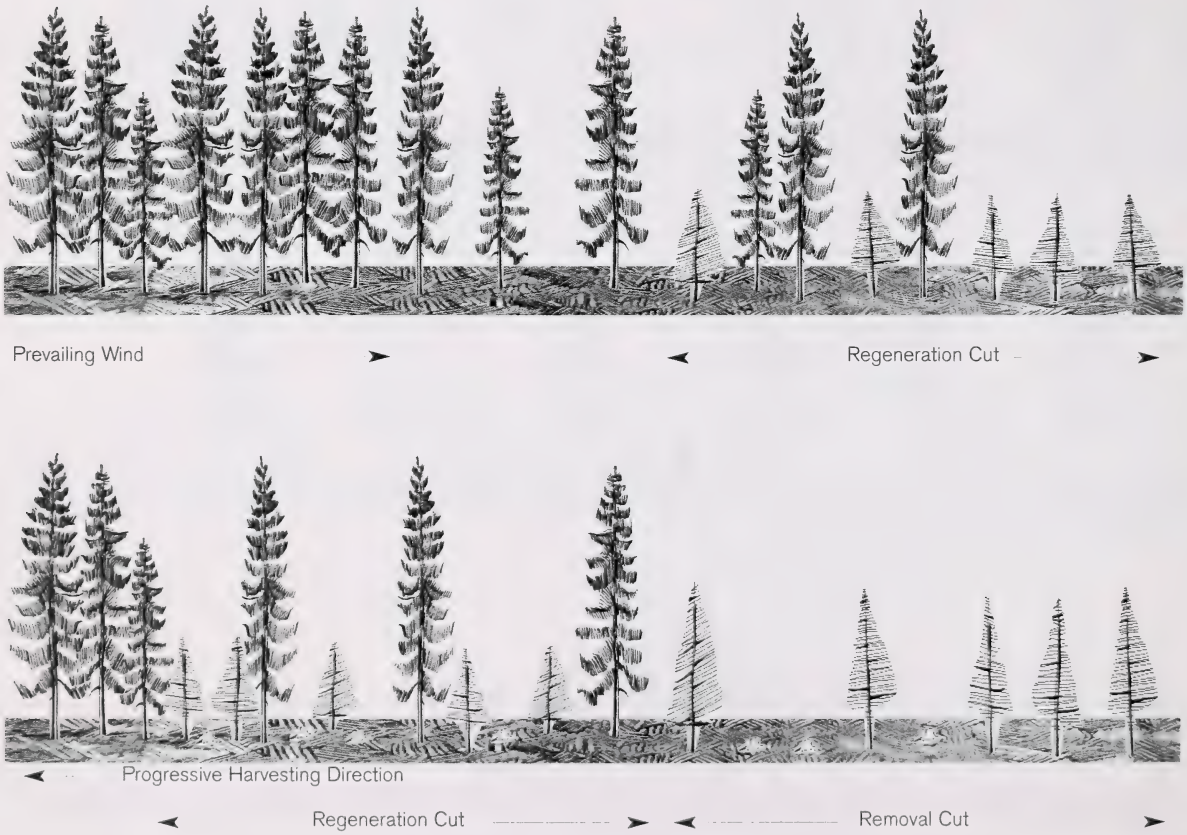
2.2.5.2. STRIP SHELTERWOOD SYSTEM

The strip shelterwood system involves a series of linear strip cuttings that advance progressively across the cutting area.

Considerations that influence strip orientation include:

- wind firmness – prevailing wind direction and storm winds;
- varying degrees of shade – exposure of the cut strip; and
- topography – contour.

For wind prone stands, start the regeneration strip cut on the lee (down wind) edge of the area to be harvested. Some years later, after the regeneration is established in the first strip, a removal cut is made on that strip and a regeneration cut is made on a second strip. There may be more than one removal cut. The final cut is made only when the regeneration can tolerate the exposure to direct sunlight. In this way, the system advances, at approximately a right angle, upwind through the cutting area (refer to Figure 14).



The strip shelterwood system progresses upwind across the cutting area of wind-prone stands.

Figure 14. Strip Shelterwood System

Figure 15. Group Shelterwood System

2.2.5.3. GROUP SHELTERWOOD SYSTEM

A group shelterwood system applies the same cutting sequence as the strip shelterwood system, but may be applied in a pattern of expanding groups or patches (refer to Figure 15).

Considerations that influence the distribution of shelterwood group cuttings include:

- using advanced regeneration (take advantage of where it exists to start the system);
- avoiding frost pockets created by group openings (radiant heat loss and depressions);
- directing the shape of the patches with consideration for landscape pattern objectives; and
- directing the shape of the patches toward strips to better facilitate the harvesting operation.

2.2.5.4. IRREGULAR SHELTERWOOD SYSTEM

In the irregular shelterwood system, residual trees are left for long periods beyond the regeneration phase. Over this extended period of time, the residual trees will initiate new age classes of regeneration, increase in wood volume and achieve non-timber stand management objectives (BC Environment, 1995) (refer to Figure 16).

2.2.5.5. NATURAL SHELTERWOOD SYSTEM

Natural shelterwood stands have a well established understory of shade-tolerant trees.

In order to take full advantage of the regeneration occurring within the natural shelterwood stand, harvesting must be conducted very carefully using a low-impact extraction method to protect the understory (refer to Figure 17).

2.2.5.6. NURSE-TREE SHELTERWOOD SYSTEM

The nurse-tree shelterwood system allows for the management of a shade-intolerant overstory with a shade-tolerant understory on the same site for a certain period of time (refer to Figure 18). The understory may exist naturally in some stands or the stand may be under planted with spruce to provide the desired understory crop.

The overstory can be managed for multiple passes in order to maintain the shade requirements of the understory until the understory is ready to be fully released.

Original Stand

Regeneration Cut

Multiple Age Classes

The leave trees are left on site for an extended period of time, eventually giving rise to multiple age classes.

Figure 16. Irregular Shelterwood System

Original stand with good quality understory.

Final Cut

A final cut on a natural shelterwood stand. The overstory is removed only when the understory regeneration can tolerate the exposure. Understory protection during the harvesting operation is the key to ensure survival of the advanced regeneration.

Figure 17. Natural Shelterwood System

Lodgepole pine overstory with a white spruce understory.

Final Cut – removal of the lodgepole pine overstory.

Figure 18. Nurse-Tree Shelterwood System

2.3. UNEVEN-AGED SILVICULTURAL SYSTEMS

An uneven-aged silvicultural system will produce stands with at least three well represented age classes. The distribution of these age classes within the stand may be balanced (equal in area and distribution) or irregular (unequal in area and distribution) (refer to Figure 19). The only way this type of stand condition can be achieved is through a selection silvicultural system.

The purpose of a selection system is to maintain or improve stand health and stand structure (tree size, quality, age and spacing across the stand). This can be achieved by removing crowded trees, lesser quality and undesirable trees first.

A selection harvest system may be applied to existing uneven-aged stands or to stands where the objective is to convert the even-aged stand to an uneven-aged stand. Converting even-aged stands is costly, time consuming and difficult. There must be strong justification prior to undertaking this course of action.

Characteristics of uneven-aged stands

- resembles a self-sustaining climax community (frequent establishment of regeneration in canopy gaps)
- provides a permanent natural seed source, which is of particular advantage on adverse sites where even-aged reforestation attempts are subject to failure
- the stand will contain a broad range of tree sizes and at least 3 well represented age classes resulting in an irregular stand structure
- generally favours the shade-tolerant, mid-late seral tree species (Subalpine forest region: white and Engelmann spruce, subalpine fir; Montane forest region: Douglas fir)
- these stands develop over extended periods of time and are frequently missed by fire

There are two legitimate types of selection harvest silvicultural systems: the group and single tree selection systems. High grading is often confused with the single tree selection system. High grading or selective logging is a type of partial cutting that removes only certain species above a certain size or of a high value. Known silvicultural requirements and/or sustained yields are wholly or largely ignored (refer to Figure 20).

2.3.1. SINGLE TREE SELECTION SYSTEM

The single tree selection system is defined as an uneven-aged silvicultural system in which new age classes are created by the removal of older individual trees or very small groups, somewhat uniformly throughout the stand (BC Environment, 1995) (refer to Figure 21).

Characteristics of the single tree selection system

- promotes or maintains an uneven-aged stand structure
- natural regeneration favours shade-tolerant, mid to late seral tree species

Potential Impacts of the single tree selection system

- the use of hand felling or small-scale logging machines is common in this system and thus may result in less site impact. However, there are examples where bunchers and grapple skidders in combination with line skidders have effectively implemented single tree selection prescriptions.
- residual trees may be damaged during the hand felling or skidding phase which may provide infection courts for heart and butt rot fungi

Eg: mC21Pl6Se4/A4FaSe (mesic, C–density pine/spruce overstory with a fir/spruce understory)
This example of a balanced, mid-successional, subalpine stand has three distinct age classes equal in area and distribution. A lodgepole pine stand may have originated from fire 140 years ago. The Engelmann spruce has established under the shade of the pine and is now pushing into the main canopy. The deeper shade created by the addition of the spruce to the overstory creates favourable conditions for the subalpine fir to establish, along with Engelmann spruce in the understory.

Figure 19. Balanced Uneven-Aged Forest

Figure 20. High Grade (Selective) Logging vs. A Selection Silvicultural System

Criteria for tree selection

- major consideration must be given to those trees left on site. The forest manager must ensure that the remaining trees are of the best quality and desired species.
- select trees to be removed that will promote the overall health and vigour of the remaining stand. Local insects and diseases must be considered. Eg: Woodpeckers will flake the bark off of trees which have beetles in them (these would be good trees to remove).

Advantages of the single tree selection system

- maintains an uneven-aged structure
- some opportunity for control over internal stand structure and composition
- protects soil stability and water quality
- promotes wind firmness of remaining trees
- likely associated with a higher visual preference and public acceptance
- no regeneration cost (assuming no under planting)
- promotes genetic improvement through the selection of superior leave trees
- promotes health and vigour of the stand (e.g., insect and disease resistance)
- maintains high forest structure that may be useful to some wildlife species
- results in a continuous supply of larger-diameter, high value trees

Disadvantages of the single tree selection system

- most complex silvicultural system to prescribe and implement. There is a requirement for long-term commitment and follow-up if the system is to be effective.
- skill required to avoid damage of remaining overstory and understory
- operational costs may be high
- roads must be left open to facilitate repeated stand entries
- repeated stand entries may cause soil compaction on skid trails
- there is a tendency to resort to high grading when market conditions are tight

Advanced regeneration is protected during the harvesting phase. High quality trees remain in an uneven-aged structure.

Figure 21. Single Tree Selection System

Application of the single tree selection system

- to the management of coniferous, deciduous and mixedwood uneven-aged stands
- this system may be useful in the management of some types of old growth forest (e.g., in the subalpine portions of the study area, Engelmann spruce and subalpine fir represent a climax community that could be maintained by a selective harvesting system)
- in the Montane portions of the study area, dense Douglas fir stands, resulting from aggressive fire control efforts, could be managed using a selective harvesting system. This will restore the semi-open Douglas fir stand associated with the inherent fire regime as well as modifying fuel contiguity.
- this system may be useful in managing areas of high visual preference such as view sheds along main highways, road corridors, areas adjacent to recreation areas or urban developments
- this system may be an appropriate system in the management of riparian zones – marking and falling individual trees may help to maintain the structure and health of the riparian forest
- this system could be used to modify the fuel structure around protected areas such as ecological reserves, wilderness areas or National Parks where natural fire regimes are allowed to operate. Modifying fuel loading and continuity around these areas may provide protection to adjacent resource values.
- this system will promote stand vigour and may provide increased resistance to attack by forest insects and disease
- this system may promote stand improvement as ungulate winter range where thermal and snow interception cover are critical to survival during late winter and early spring. Increased light to the forest floor could promote browse production for food within the stand and still provide high forest for thermal cover and snow interception (reduced snow depth for mobility). In some cases however, the opposite is true. If trees are removed individually and relatively uniformly over the stand, the crown closure and snow interception effect of interlocking crowns will be reduced and mobility may be reduced.
- selection cuts may be under planted to create a change in forest species composition

2.3.2. GROUP TREE SELECTION SYSTEM

Group tree selection is defined as a silvicultural system that removes trees in small defined groups or strips, called regeneration openings, to perpetuate an uneven-aged stand condition. The maximum width of these regeneration openings could be set at twice the height of the adjacent mature trees (Smith, 1986). The maximum width of these regeneration openings could be set at twice the height of the adjacent mature trees (Smith, 1986) (refer to Figure 22).

This system may be employed to convert a presently even-aged stand into an uneven-aged stand. The area being managed under this system would have to be "area regulated" so the desired representation and distribution of each age class would be present in the stand. Once achieved, each cutting cycle would yield a similar volume of wood on a perpetual basis.

Example: A balanced, uneven-aged stand with 6 age classes and a maximum age of 120 years would provide a constant volume "x" using a 20-year cutting cycle. Assuming equal site productivity, the area occupied by each age class would be approximately 16.5% of the entire stand. In this example, the forest manager could perpetually harvest 120 year old trees (volume "x") from this stand by group selection harvesting with a 20-year cutting cycle.

Figure 23 illustrates in plan view an area regulated stand showing an approximately equal area and balanced distribution of 6 age classes. In addition, it surrounds an area being managed with two age classes on a 20-year cutting cycle. Three 120 year old groups may be harvested from the outer area every 20 years while one 200 year old group may be harvested from the inner area at the same time. This age class distribution concept is applicable within a nested hierarchy of scales and can provide the basis for even flow fibre supply. The concept of variable age rotation with patches larger than that used in group selection is applicable under other systems including even-aged (Peterken et. al., 1992).

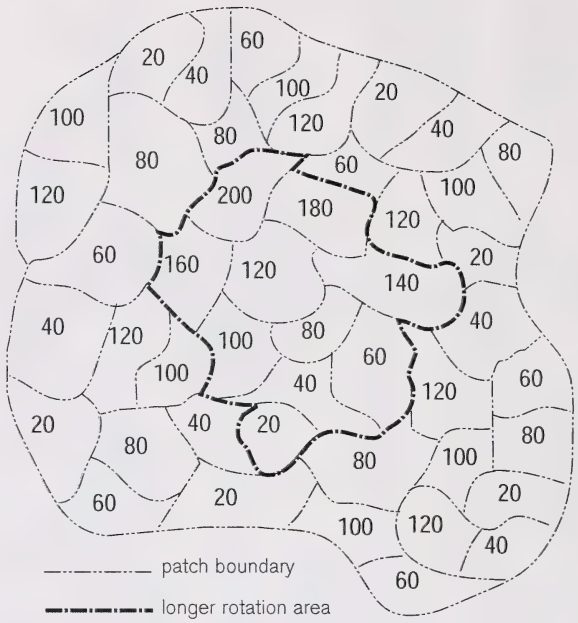


Figure 23. Example of Area Regulation With Variable Age Rotation

The group selection system will create a patchwork of small openings within the stand that will regenerate as different age class patches.

Figure 22. Group Selection System

Characteristics of the group selection system

- promotes or maintains an uneven-aged stand structure
- natural regeneration – ingress from the perimeter (may require some spot planting towards the middle of the opening)
- favours shade-tolerant climax species on north aspects and shade-intolerant mid to late seral species on south aspects
- stand improvement comes only from genetically improved planted stock, if desired
- the centre of the cutblock opening can favour early seral species, while edges of the cutblock, under shade, can favour mid to late seral species

Advantages of the group selection system

Similar to the single tree selection system, with the following additions:

- cutting in groups or strips results in less damage to the residual stand
- better cost recovery for harvesting over the single tree selection system because the forest is more regulated
- promotes small scale logging operations which may be beneficial for local small businesses
- if selection systems are properly designed, they will facilitate mechanical harvesting and skidding operations to maximize cost efficiencies
- avoids the drastic changes in soil moisture and site exposure inherent with clearcuts and patch cuts

Disadvantages of the group selection system

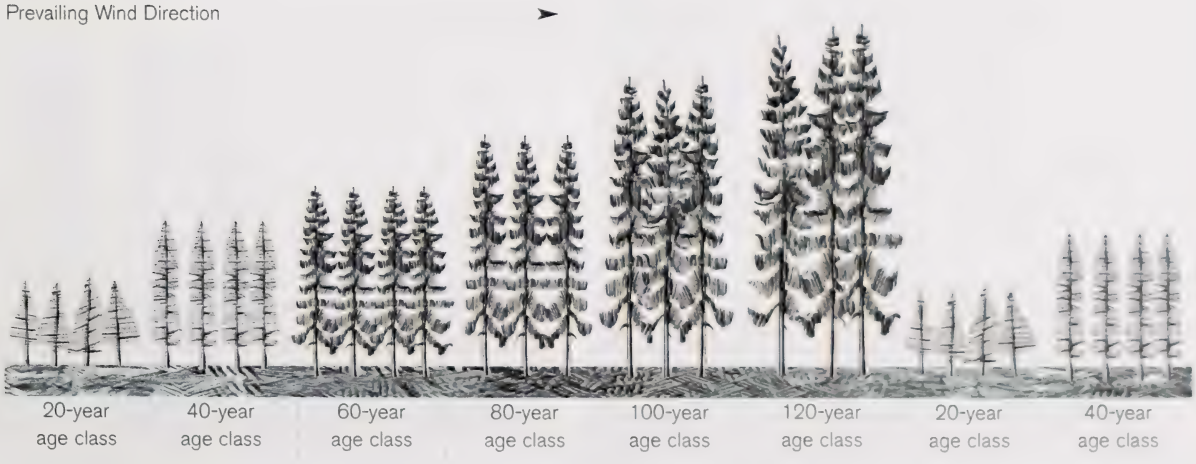
Same as for the single tree selection system (see page 24).

Application of the group selection system

- this system would have similar applications as the single tree selection system except it may not be as useful in the management of riparian areas
- this system may apply well within the Miscellaneous Timber Units as a local small business opportunity and has been used as such in areas of British Columbia
- this system may be useful as one method of fuel modification. Head fire intensity may be reduced by creating small gaps in the canopy.

2.3.3. STRIP SELECTION SYSTEM

The strip selection system was designed to accommodate harvesting in European forests that were prone to windthrow damage. It has the advantage that it concentrates each age class into distinct and separate parts of the stand. Where wind protection is desired, strips should be removed into the prevailing wind (refer to Figure 24). The system also has application in areas where windthrow is not a primary management concern.



The strip selection system should progress upwind to reduce blow down potential.

Figure 24. Strip Selection System

Characteristics of the strip selection system

Similar to the group selection system, with the following additions:

- strip may be of varying width dependent upon objectives
- the centre of the strip opening can favour early seral species, while edges of the strip, under shade, can favour mid to late seral species
- strips may also be oriented to maximize the benefits of shade or sun to promote the desired regeneration species or degree of visibility from key locations (refer to Figure 25)

Advantages of the strip selection system

Similar to the group selection system, with the following additions:

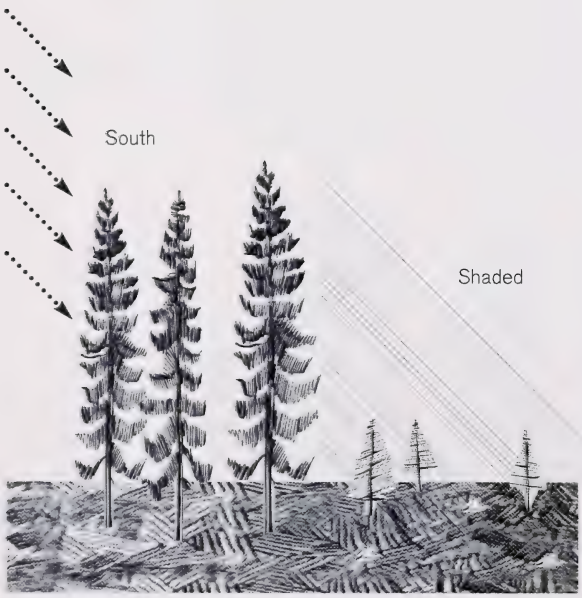
- with proper orientation, may be used in visually sensitive areas
- may allow for more efficient use of machinery than other selection systems

Disadvantages of the strip selection system

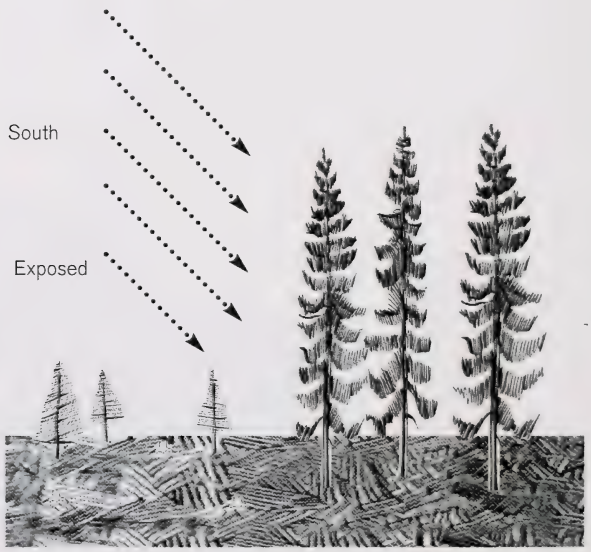
- highly unnatural form can result in reduced visual quality dependent upon viewing position and the variability of the inter-strip distance and the strip width

Application of the strip selection system

- this system may be useful to provide areas of continuous fuel modification



Progression of strip cutting from north to south will promote shade for shade-tolerant regeneration.



Progression of strip cutting from south to north will promote sun for shade-intolerant regeneration.

Figure 25. Strip Cutting

3. The Components of a Silvicultural System

Silvicultural systems consist of both harvesting and regeneration methods and both components must be considered together. Harvesting includes partial and whole tree logging with the material removed from the site by ground based, cable and aerial extraction methods. Regeneration methods include both natural and artificial techniques.

3.1. HARVEST METHODS

A harvest method is the physical process by which the harvesting cycle is completed. This includes falling, skidding, landing, loading and hauling of wood from the logging site to the milling facility. This also includes consideration of where limbing and topping occurs and debris disposal.

The various harvest methods are described in the following sections. The methods are grouped by the categories of: ground based, cable and aerial extraction methods. These methods are a combination of a felling unit, skidder, processor, loader and transport unit that commonly operate together as a team. Each of the methods have potential application in the southern east slopes. The following descriptions are presented as options and represent a range of extraction methods that may be considered in order to help achieve specific, stand-level management objectives.

Most harvest methods involve partial removal of the tree from the site although there are some applications which require entire tree logging (discussed below).

3.1.1. WHOLE TREE LOGGING

Whole tree logging or push logging involves removing the entire tree including the main root from the site. This method is used in the control of root disease or in the conversion of forest land to open pasture, where stump removal is desired. Whole tree logging may be carried out in one of two ways:

- trees are harvested using a tracked back hoe, with an opposable thumb, that can grasp the tree and lever it free from the ground. The harvester will shake loose the dirt and set the tree down in bunches for skidding. The grapple skidder requires a boom mechanism that allows it to lift the tree butts higher than normal, so the roots are clear of the ground during the skid. This requires a higher degree of processing at the landing to remove the roots along with the limbs and tops, which accumulate into large debris piles for burning at the landing. Processed logs are loaded and transported to the mill. This method is best suited to larger diameter trees.
- root removal may also be achieved by conventionally logging the site first and subsequently removing the stumps. Trees are skidded to the landing, processed, loaded and hauled to the mill in the usual manner. The stumps remaining on site are excavated from the ground and piled using a brush rake, back hoe or mounted on a cat. Stumps may be left where they are excavated or they may be piled on site for burning. This

method is best suited to smaller diameter trees with smaller roots that can be excavated from the ground by the brush rake or back hoe.

Advantages of the whole tree logging method

- effective control of root disease
- higher visual preference where forest land conversion is desired (no stumps and a "clean site")
- creates large, loosely-compacted plantable sites with reduced competition promoting seedling establishment and vigour
- where stumps are excavated and left on site (i.e., not piled and burned), they may provide microsite shelter and visual breaks for wildlife movement
- where stumps are excavated and left on site, the stumps eventually break down causing a slow release of nutrients into the site

Disadvantages of the whole tree logging method

- increased cost of operation
- requires specialized harvesting equipment
- higher number of skid cycles with fewer trees as the stumps often reduce the load
- may reduce nutrient capital on site
- large debris piles which accumulate at the landing require disposal
- burning of root piles is difficult and usually incomplete due to the high moisture content of stumps and excessive amounts of soil in the piles
- higher potential for site and soil impact from root displacement and skidding
- potential for localized soil damage caused by extreme heat from burning debris pile (high residency time associated with slow burning stumps – particularly larger landing piles)
- where stumps are removed from the site, elk and cattle grazing may be encouraged which may cause damage to regeneration

Application of the whole tree logging method

- this extraction method may be an effective control for root diseases. Removing the stump during the harvesting phase removes most of the inoculum load from the site. This dramatically reduces the spread of root disease.
- this extraction method may also be considered where land is being converted from forest land to open pasture. The removal of stumps may be desired where aesthetics or open access across the pasture is important.

Limitations to the whole tree logging method

- tracked feller bunchers may operate on slopes up to 55%; however, rubber-tired grapple skidders, even with chains, are limited to slopes less than 45%. Skidders with four independent tracks, in place of the wheels, may be used to reach up to 55% slope.
- mechanized harvesting operations may be limited by an excessive amount of dead fall, loose rocky soils or surface frost, or other conditions on steep slopes that reduce or prohibit mobility
- mechanical stump removal may cost between $800 to $1,200 per hectare over and above the cost of harvesting and regeneration treatments
- stump removal may result in a reduction of the nutrient capital from the site, however, the effect is not well documented. To some extent, the effect is reduced because the bulk of the nutrient load comes from the high volume of fine roots, which remain in the soil as they break away from the main root mass when it is removed.

3.1.2. GROUND BASED HARVEST METHODS

Several ground based harvests systems are currently in use in the industry. The following sections outline mechanical harvesting and other variations, including hand falling and line skidding, as well as cut-to-length operations.

3.1.2.1. MECHANIZED HARVESTING

The mechanized or conventional harvesting method involves a feller buncher, grapple skidder, wood processor and self-loading trucks or loader with non-self-loading trucks. Advances in technology have promoted the efficiency and safety of mechanized timber harvesting.

The feller buncher fells trees and sets them into bunches to facilitate efficient skidding (this also promotes understory protection). The grapple skidder skids bunches of trees to the roadside where they are processed for loading. Processing involves the removal of branches and tops of the trees using one of a variety of different types of machines. Typically in this type of operation, a stroke delimber is used to process the logs. Processed logs are re-piled along the roadside for loading. Self-loading trucks will load the logs from the roadside and haul them to the mill (refer to Figure 26).

Advantages of the mechanized harvesting method

- can operate both summer and winter
- the feller buncher can operate 24 hours per day with overhead lights mounted on the unit
- efficient and safe because operators remain in the cab of the unit
- a high degree of understory protection may be achieved by careful placement of skid bunches and cautious skidding

Disadvantages of the mechanized harvesting method

- roads, landings and skid trails within the cutblock may cause soil compaction of sensitive forest soils (fine textured soils are especially susceptible)
- the harvestable tree size is limited to the capacity of the cutting head on the feller buncher
- feller buncher maneuverability may be limited on sites with a high slash loading

Figure 26a. Timco 435 Feller Buncher (233 hp) with 22 inch Quadco Cutting Head. The tilting table and tilting cutting head allow operation on steep slopes (up to 55% slope).

Figure 26b. Timberjack 480 B Grapple Skidder (177 hp). The operation of rubber tire skidders is limited by steep slopes (up to 45%).

Figure 26c. Timberjack 480 T Grapple Skidder (177 hp) on four independent tracks can operate on slopes up to 55%.

Figure 26d. Linkbelt 3400 Stroke Delimber with telescoping boom, delimbs and tops logs at the landing or roadside.

Figure 26e. Kenworth Logging Truck with Serco 160 picker. This is a 4-axle, highway truck that can carry approximately 27-30 m^3 of wood when fully loaded.

This sequence of photographs represents a typical or conventional, mechanized logging operation.

Figure 26. Mechanized Harvesting Equipment

Method	Slope (%)			Stump Diameter (cm)			Skid Distance (m)			Leave Trees (per hectare)		
	0 - 25	25 - 40	> 40	< 20	20 - 30	> 30	< 150	150 - 300	> 300	< 300	300 - 700	>700
horse	+	-	-	-	0	+	+	-	-	+	+	+
buncher/grapple	+	+	-	+	+	+	+	0/-	-	+	-	-
buncher (steep slope)	0	+	+	+	+	+	+	0/-	-	+	+	+/0
cut to length	+	-	-	+	+	+	+	0/-	-	+	-	-
hand fall/line skid	0	0	-	-	0	+	+	0	-	+	+	+

Figure 27. Generalized Harvest Method Guidelines

Application of mechanized harvesting

- this extraction method may apply best to less sensitive drier sites where road access is possible and the average skid distance is less than 100 meters. The typical cost of this type of harvesting operation may range from $18 to $20 per m^3 of wood delivered to roadside. In the mountain regions, the cost is higher, ranging from $20 to $24 per m^3 of wood delivered to the roadside, due to the terrain and extended skid distances. (Hauling costs are not included in these figures as they are variable depending on the type of loading system, distance to the milling facility and weight restrictions.)
- during dry summer conditions, this method may be used on sites that have a low to moderate rutting or compaction hazard
- sites with a moderate to high rutting or compaction hazard may be operated using this method during frozen ground conditions
- this method has application where understory protection is an objective. The feller buncher controls the placement of the tree into skid bunches and can orient those bunches down slope to facilitate efficient skidding.

Limitations of mechanized harvesting

- some tracked feller bunchers, such as the Timco, may operate on slopes up to 55% or more; however, the rubber-tired grapple skidders, even with chains, tend to be limited by slopes over 45%
- the mobility of tracked feller bunchers may be limited by excessive amounts of dead fall, loose rocky soils or surface frost conditions on steep slopes

3.1.2.2. HAND FALL/LINE SKID

The hand fall/line skid extraction method involves the felling of trees, by a faller, and skidding with a rubber-tired, line skidder.

An experienced faller fells the trees. A line skidder, equipped with a rear-mounted winch containing 10 to 20 bell-coupling chokers attached to a main line cable, will yard up whole trees and deliver them to the landing. Trees are processed at the landing by a chainsaw operator who limbs and tops the trees. The skidder is used to square up the log deck and push up the wood debris into piles. Logs are then loaded onto a log truck by a wheeled loader or loaded by a self-loading truck and hauled to the mill (refer to Figure 28).

Equipment Description Corresponding to Figure 28

Faller

- felling direction is influenced by tree form, lean and weight
- professional fallers can fall from 50-100 m^3 per day depending on site conditions (Breaddon, 1983)

Figure 28. Hand Fall/Line Skid

- some limbing and bucking can be done where the tree falls to reduce debris piles at the landing and to promote nutrient recycling on site

Clark 666 Line Skidder
- a full skid will contain 7 m^3 of wood or more
- may skid from 75-110 m^3 to the landing per day where the skid distance is less than 100 m
- the optimum average skid distance should not exceed 100 m, with a maximum skid of 300 m
- the skidder performs 4 functions: skids wood to the landing, delimbs some of the branches with a front mounted blade, squares up the log deck and pushes wood debris into piles

Cat 980 Loader
- the 270 hp. diesel may lift up to 35,000 lbs (4-6 m^3 per clam)
- has a 30 mph road speed to service several landings or move from block to block

C500 Kenworth, self-loading truck with a heel boom loader
- loading and unloading time is about 20 minutes

Advantages of the hand fall/line skid extraction method

- site and soil impact is somewhat reduced by hand falling (skidding creates most of the disturbance)
- hand falling is not limited by steeper slopes, although safety becomes more of an issue as slopes increase

Disadvantages of the hand fall/line skid extraction method

- production is reduced compared to the feller buncher because it takes longer to hand fall the trees
- production is further reduced during the winter with cold temperatures and deep snow conditions
- hand falling skill and experience is required (hand falling is very dangerous work)
- hand falling becomes more dangerous and time consuming as the slash loading increases

Application of the hand fall/line skid extraction method

- this method is used commonly in small-scale wood operations, where the expense of mechanized harvesting equipment may be limiting. Under good operating conditions, the cost of this method may range from $16 to $20 per m^3 of wood delivered to the landing. Under difficult operating conditions, the cost of this method may range from $20 to $24 per m^3 of wood delivered to the landing (hauling costs excluded).
- this method may be used on sites where the amount of downed woody debris (slash) impedes the use of tracked equipment
- this method may be used on sites where the average diameter of trees exceeds the capacity of the cutting head on the feller buncher
- this method may be in the management of riparian zones. Individual trees may be marked for removal, hand felled and yarded out by the line skidder which can reach well into the riparian zone with its mainline cable. The advantage is that no heavy equipment enters the riparian zone.

Limitations of the hand fall/line skid extraction method

- hand fallers are less limited by slope then the rubber-tired skidder, although safety for the faller becomes an issue on steeper terrain. Rubber-tired skidders, even with tire chains, are usually limited to slopes less than 45%.
- hand falling is hampered by deep snow conditions
- hand falling/line skidding is not an appropriate choice where understory protection is an objective. In some cases, the faller has little choice where the tree will fall. The skidder often pulls logs across the slope before getting pointed down hill toward the landing. Logs sweeping across the ground will cause severe damage to the advanced regeneration.

3.1.2.3. CUT-TO-LENGTH

The cut-to-length extraction method is based on the team work of a harvester and a forwarder. This efficient system was developed in the Nordic countries in the 1960s and is presently being used in many parts of the world. There are a few cut-to-length operations in Alberta and British Columbia (refer to Figure 29).

Trees are felled, limbed, cut to a pre-determined length (commonly a 20' 6" bolt), sorted and piled at the stump by the single grip harvester. Diameters and log lengths are entered into the harvester's computer for accurate bucking and topping. The forwarder is a rubber-tired unit with a grapple that picks up the bolts and loads them onto a deck at the rear of the unit. Once loaded, the forwarder delivers clean wood to the roadside or landing. At the landing, a loader loads a "B-train" truck which transports logs to the mill.

Equipment Description Corresponding to Figure 29

Timberjack 1270 Harvester with Pierce 20" cutting head
- high floatation tires
- harvester will fell, delimb, cut-to-length, scale, sort and pile at the stump
- equipped with an on-board computer, production figures are reported daily
- processes approximately 14 m^3/hr
- has a 28-foot reach with the cutting head

Timberjack 1210B Forwarder
- high floatation rubber tires with a slip-on-track create minimal ground pressure
- delivers approximately 17 m^3 of processed wood to the landing per hour with an average skid distance of 300 m or less
- unloading time is approximately 5 minutes

Figure 29. Cut-To-Length Method
NOTE: Photographs used with the permission of Crestbrook Forest Industries

Cat 950E loader and Kenworth B-train Truck

- the loader takes 20 minutes to load the B-train at approximately 4 m per clam load
- this highway B-train will carry 35-40 m^3 when loaded

Advantages of the cut-to-length extraction method

- does not require other processing equipment
- minimal ground pressure allows a longer operating season (extended during wet conditions)
- logs are processed in front of the harvesting unit, which creates a ground-protecting mat of branches and tops that the harvester and forwarder can travel over (this further reduces ground pressure)
- processing of logs at the stump allows branches and tops to decompose on site (good on nutrient-poor sites)
- landings are much smaller (no debris pile at the landing)
- this system provides for understory protection between skid roads
- very safe operation as operators are in the cab during the entire process

Disadvantages of the cut-to-length extraction method

- the forwarder must move straight up and down slope when loaded because the unit is top heavy
- an efficient system requires two harvesters for one forwarder to maximize the production of the forwarder
- a refit at the mill may be required to accommodate pre-cut logs
- the dangling cutting head cannot push through deep snow to achieve a low cut stump during winter operations

Application of the cut-to-length extraction method

- harvesters and forwarders come in various sizes allowing them to be used in any of the silvicultural systems. Smaller units may apply better to the shelterwood or selection silvicultural systems because they are more maneuverable.
- this method is beneficial on nutrient-poor sites with thin soils. Scattered debris creates microsite shelter for regeneration and a gradual release of nutrients over the site. Organic material will eventually mix into the soil to reduce bulk density and improve the moisture holding capacity of the soil.
- this method may apply well to commercial thinnings, where protection of the leave trees is critical. Some fire-origin stands may require advanced cleaning by hand to reduce stand densities and promote diameter growth.
- this method may also apply to intensively managed, second rotation stands with a more regulated structure and less downed wood to obstruct maneuverability

Limitations of the cut-to-length extraction method

- generally limited to slopes less than 40%, even with slip on tracks
- the forwarder must be able to get high enough in the block to drive down to the logs to be loaded. The forwarder must be able to position itself beside the logs to be able to pick them up.
- the size of the cutting head will limit the size of the harvestable tree. Various sizes of harvesters and forwarders are available.

3.1.2.4. HORSE LOGGING

Horse Logging is a method of hand logging where horses supply the power to skid logs to the landing (Figure 30). This method is steeped in the traditions of old style logging. Oxen were the original source of power to skid logs out of the bush, but were replaced by horses which are more manageable. Horse logging is still a viable method of logging.

In today's horse logging operations, trees are felled, limbed and topped at the stump using a chainsaw. For ground skidding, the log is manually choked and hooked up to the grab hook on the team's harness. Often logs are top skidded to reduce gouging during the skid. Once at the road side, logs are pulled onto the log deck using a variety of home built deckers. Logs are picked up by a self-loading truck and hauled to the mill (refer to Figure 31).

Considerations for horse logging

- over short skid distances, with small diameter trees, anti-friction devices are generally not worthwhile as they reduce maneuverability and add weight
- a viable horse logging operation consists of two people with a team of two horses that must deliver 30 m3 of logs to the roadside per day. A level skid distance of not more than 150 m is optimum. Larger trees with a lot of limbs slow production.

Hand felled trees are skidded out of the bush by a team of horses.
Figure 30. Horse Logging

- once a skid trail has been established, rub trees or posts should be left in place to protect other trees from rub damage. Rub trees are taken out last.

Advantages of the horse logging

- low cost to set up – very portable
- wide variety of applications
- much less noise associated with the horse logging operation
- may have a higher degree of public acceptance

Disadvantages of the horse logging

- slower production rates compared to machinery
- possible introduction of weeds and undesirable plant species into the forest environment from horse feed

Application of horse logging

- useful in patch cuts or small clearcuts where the cost of transporting conventional equipment is not economically feasible
- for a selective silvicultural system
- useful on sites where the protection of advanced regeneration is important. Guided skid loads may avoid patches of regeneration and are very narrow. There are no branches on the logs being skidded which may scrap up against regeneration.
- good for the removal of seed trees once regeneration has been established
- good on sites with thin soils as debris is evenly distributed across the block. This will provide shelter for the establishment of regeneration and a slow release of nutrients back into the soil as the debris breaks down.
- this method would apply in areas where stand management is desired but there is no tolerance for motorized equipment. This may include special management areas such as riparian areas, wildlife travel routes or areas adjacent to critical wildlife habitat, or recreation areas where the sound of machinery is not desirable.
- specific stand management objectives, within protected areas, provincial or national parks, may be achieved by horse logging as a historical demonstration
- timber on rugged upper slopes (up to 70%) may be more accessible to horses than to machinery (in this case, leave branches on during the skid to prevent the log from sliding too fast)

Figure 31. Logs are loaded and hauled to the mill.

Limitations of horse logging

- production may be the only limitation to horse logging, other than the availability of experienced horses and horse loggers

3.1.3. CABLE YARDING SYSTEMS

There are many types of cable yarding systems which have been modified and adapted over the years. The application of such systems comes from:

- intensive forest management;
- adverse topography with sensitive forest soils; and
- high cost and detrimental impacts of mountain road building.

In addition to understanding the process and application of the many variations of cable logging systems, the forest manager requires considerable expertise for the mechanics of rigging, anchoring, setting guy lines and operating these systems safely. It is not possible to cover all aspects of cable yarding systems in this brief section. However, references used in this section may guide the reader to more specific information.

As with any technical process, there is a language that is specific to cable yarding systems. Terminology must be understood for effective communication between forest managers, planners, engineers and loggers.

Ground lead, high lead, skyline and **balloon** are general categories of cable yarding systems which are discussed in this section. As the names would imply, the amount of lead, or log lift from the ground, in each yarding system defines each of these categories (refer to Figure 32). **Yarding** is the term used to describe the movement of logs from the stump to the landing by a yarding engine or donkey.

Extensive planning is required for a cable yarding operation to be successful. Landings are required for log storage and must be large enough to provide operating room for equipment and transport away from the site by trucks. Landing locations must also avoid blind leads and promote the correct deflection angle (refer to Figure 33) for safe yarding. A **blind lead** occurs when the line of site from the **headspar** to the **tailhold**, referred to as a **span**, is obstructed. Anchor points for

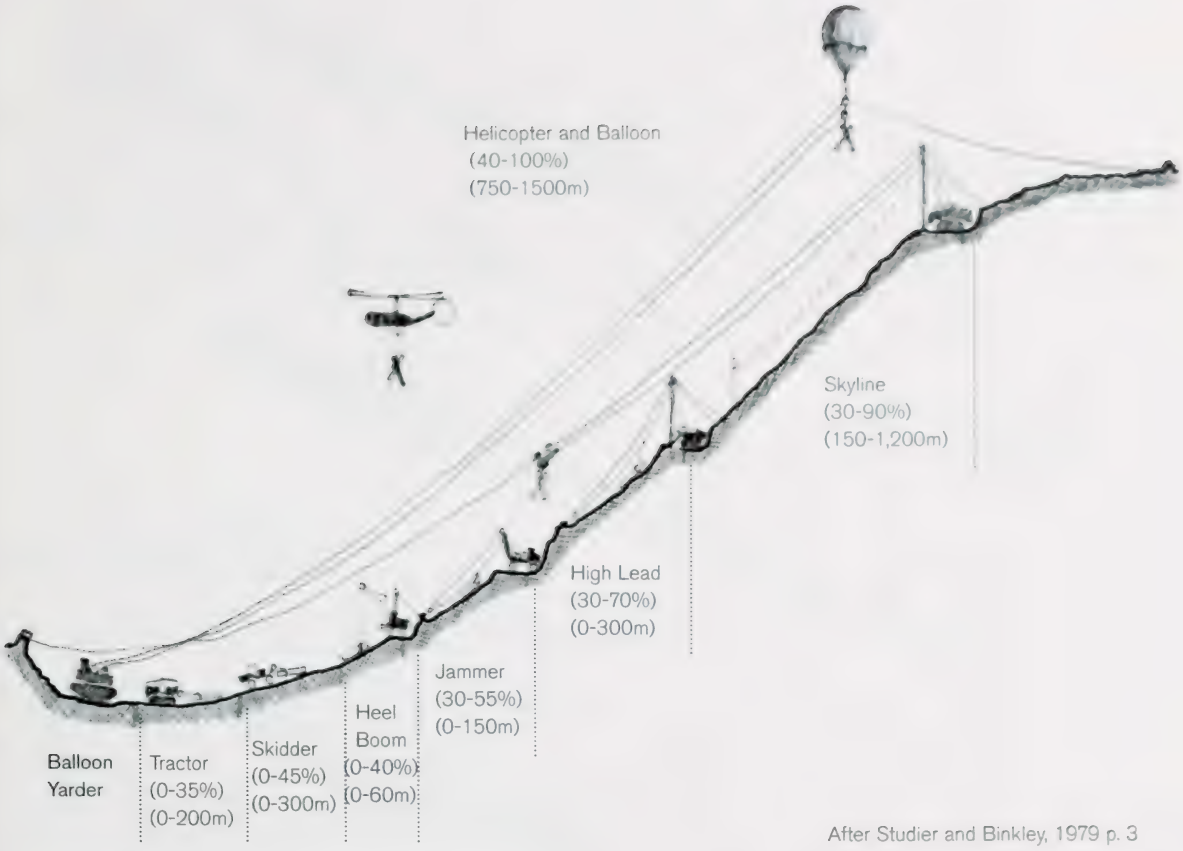


Figure 32. Comparison of Various Yarding Methods

guy lines and skylines must also be available or made. A **setting** is the area logged by one yarding position. A **skyline road** is the area within the length and lateral yarding width of any given skyline setting. A **skyline corridor** is a narrow clearing width needed to allow the passage of the carriage and logs when yarded in partial cuts or thinnings (Studier and Binkley, 1979).

3.1.3.1. GROUND LEAD SYSTEM

"Steam pot" yarders were designed to yard logs to the landing along the ground. Log hang-ups are common (especially with high stumps) and site disturbance is a major problem.

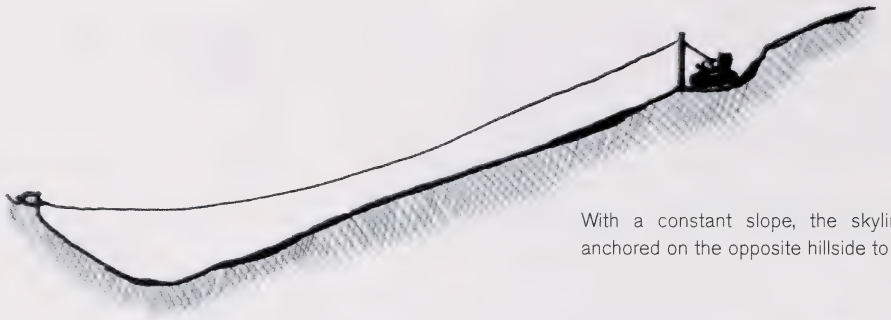
In a ground lead system, trees are felled, limbed, topped and bucked to length, using a power saw, at the stump. Trees are manually choked and yarded along the ground to the landing. This requires a site with a fairly constant slope and low cut stumps. This is the least efficient of the cable systems and is not commonly used due to hang-ups on stumps or rocks. Gouging of the ground, during the yarding operation, may cause an unacceptable level of ground disturbance and erosion potential.

3.1.3.2. HIGH LEAD SYSTEM

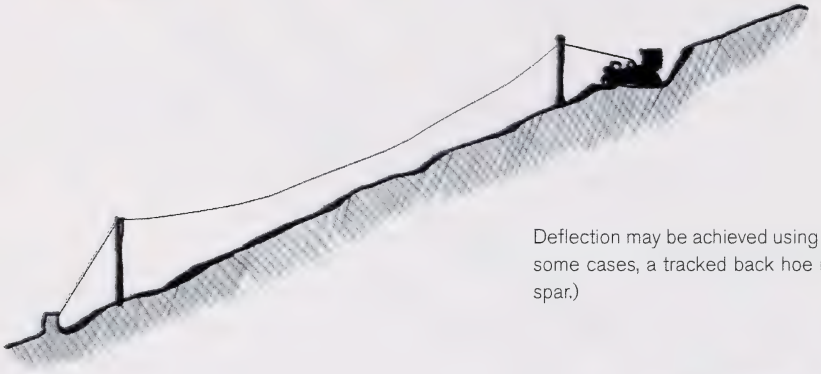
This system is commonly used on the west coast where logs are extremely heavy and can not be lifted in a skyline operation. The high lead system is mainly an uphill operation, where the choker cables are hauled to the wood with the haulback line. Logs are manually choked and yarded to the landing with the main line where they are unhooked. In a high lead system, lift is not provided to the log until it is approximately three times the height of the spar from the landing (Studier and Binkley, 1979) (refer to Figure 34). This timber extraction method is compatible with the clearcut silvicultural system only.

Maximum Yarding Distance and Direction: 300 m up slope, 180 m down slope.

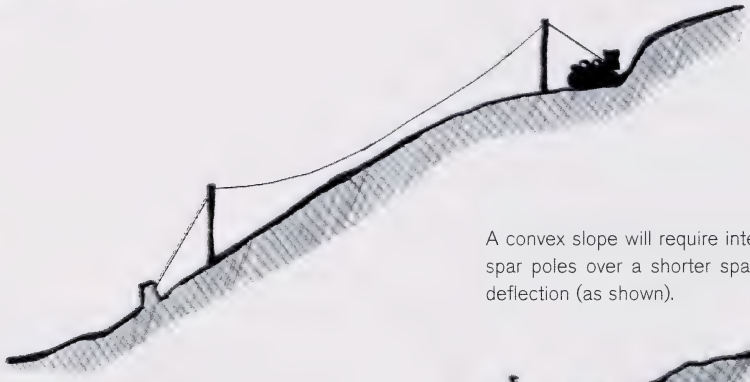
Towers range in height from 10-33 m (telescopic). The under carriage may be tracked or trailer mounted. In either case, a road must be constructed to set up the head spar and to haul wood from the landing.



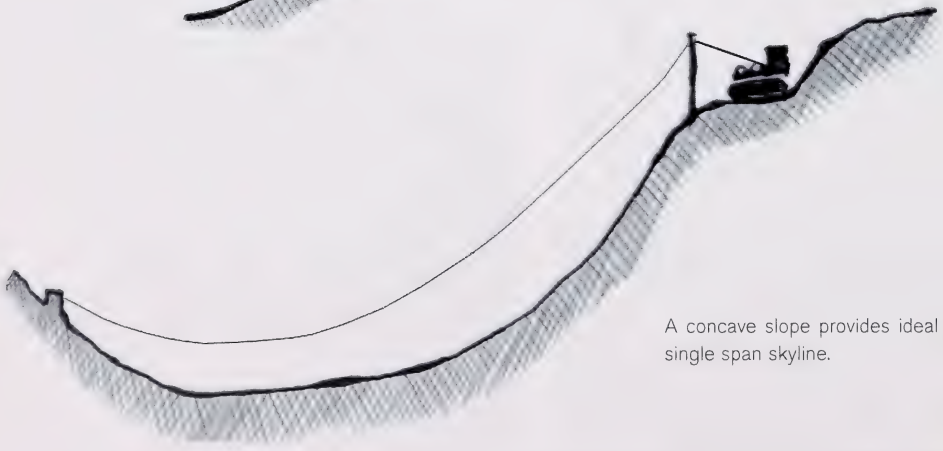
With a constant slope, the skyline system may be anchored on the opposite hillside to provide deflection.



Deflection may be achieved using an elevated tail spar. (In some cases, a tracked back hoe may be used as the tail spar.)



A convex slope will require intermediate supports or two spar poles over a shorter span to attain the necessary deflection (as shown).



A concave slope provides ideal ground conditions for a single span skyline.

Deflection depends on topography. Convex slopes referred to as the "Kootenay role" are not compatible with skyline systems without intermediate supports.

Figure 33. Deflection Angles for High Lead Systems

The high lead system is most commonly associated with the clearcutting silvicultural system. (Illustration after Cable Logging Systems, Studier and Binkley, 1979, p. 110)

Figure 34. High Lead Cable System

Production

- this system requires 4-5 people and may yard up 50-100 pieces per day (Studier and Binkley, 1979)
- production is affected by line speed, yarding distance, obstructions and snow

Operational characteristics

- lateral yarding within the setting is limited to the length of the chokers
- a fire hazard is created during the yarding operation by high-speed friction created at the pulley blocks which lie on the ground
- a high amount of ground disturbance occurs as logs are skidded along the ground until they reach the head spar

Application of the high lead system

- this system may be useful on slopes up to 70% where the desired silvicultural system is clearcutting

Limitations to the high lead system

- sites where deflection and high road access can be achieved
- a high amount of site disturbance is associated with this system as logs gouge the ground during yarding. The skid paths, which run straight up slope, create erosion channels.

3.1.3.3. SKYLINE SYSTEM

The skyline system consists of a cable way (wire rope) stretched taught between two spars that is used as a track for the carriage (a wheeled device that ridges on the skyline) for the purpose of lifting logs above the ground during the yarding cycle. Landings may be located at the top or the bottom of the cutblock (refer to Figure 35).

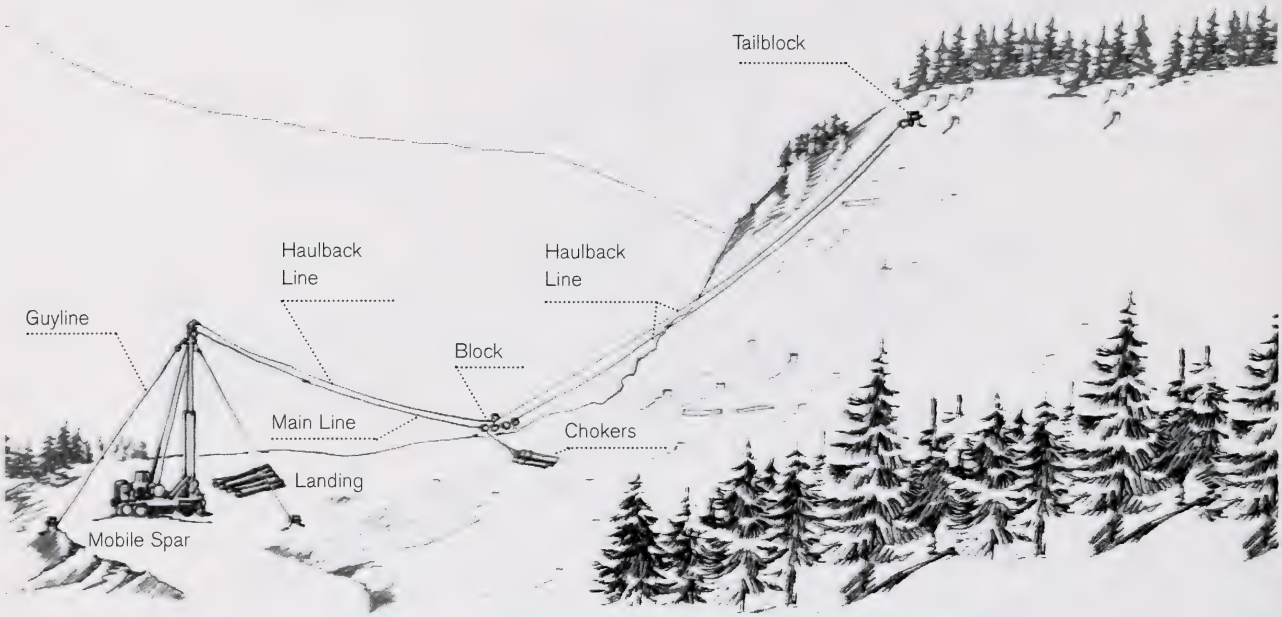
In general, there are three main groups of skyline systems; each have several variants.

Standing or tight skyline – a single span is anchored at both ends to maintain a fixed tension on the main line cable.

Live or slack line – the skyline may be raised or lowered by the yarding engine by a separate drum. This provides control over the tension on the main line cable.

Running skyline – the carriage rides both the main line and haulback line which provides control, through breaking power, to yard both up slope and down slope. Applying breaking power to the haulback line provides additional lift to the logs.

With any of the skyline variants, trees are felled by hand and choked manually. In the running skyline, the swing-boom yarder has the ability to rotate so logs may be yarded up along side the yarding engine where they are unhooked. A grapple skidder skids the logs out of the way to another landing a short distance away for processing. Once processed, logs are pushed into a loading pile for a self-loading truck. Wood debris is pushed off to the side and burned during safe burning conditions (refer to Figure 36).



Running Skyline yarding down slope. (Illustration after Cable Logging Systems, Studier and Binkley, 1979, p. 154)

Figure 35. Running Skyline With Chokers

Maximum Yarding Distance : 400 m up slope , 200 m down slope.

The yarding engine has two interlocking drums that allows for breaking control of both the main line and the haulback line. This provides the necessary control for both uphill and downhill yarding. This system is efficient with a single span setting, although, deflection becomes more important. Multi-span settings or tail spars may be used to overcome insufficient deflection, but the rigging becomes more complicated and set-up takes longer.

Production

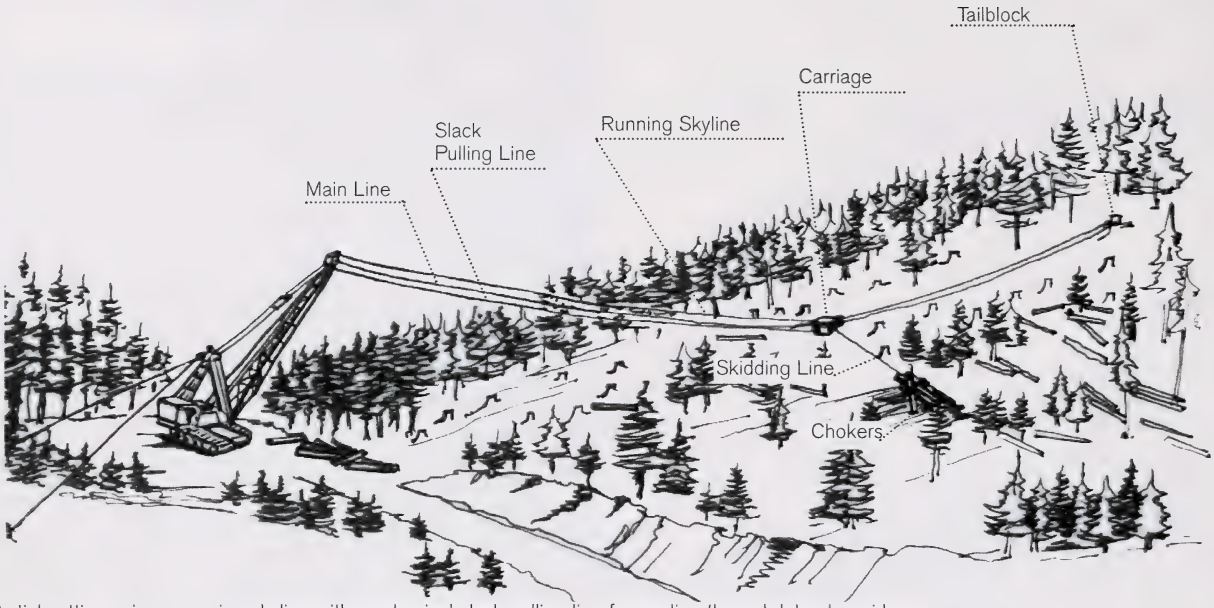
- this system requires 4-5 people and may produce 80-160 m^3 per shift (Breadon, 1983)
- over a maximum 300 m span, the yarding cycle will take approximately 5 minutes
- maximizing the payload of each yarding cycle is very important and requires experience and communication between the cable operator and the chokermen
- production is affected by line speed, yarding distance, obstructions and snow

Application of the skyline system

- on a site with a clearcut silvicultural prescription, slopes range from 30-70% with high elevation pitches to tree line up to 90%; trees may be removed from the site using a combination of extraction methods while achieving a low ground impact
- if the site has the appropriate deflection (minimum of 5%), a combination of running skyline and helicopter may be used. Eg: A high road would be constructed into the site to establish the position of the mobile head spar and log landing site. A distance up to 400 m (300 m optimum) may be cable yarded up slope using a running skyline set-up. Using the same position for the mobile spar, a single span distance (up to 200 m) could be yarded down slope to the same landing site. If it were desirable to remove timber higher up slope, that could be achieved with a helicopter operation. A log landing would be required, with truck access, within 2-3 km of the logging site.
- a running skyline system with a mechanical slack pulling carriage may be used for thinning, partial overstory removal or clearcutting. The slack pulling line, controlled from the mobile spar, runs out from the main carriage for lateral skidding (refer to Figure 37). This allows for a much wider block, but deflection is still required over the entire cable setting.

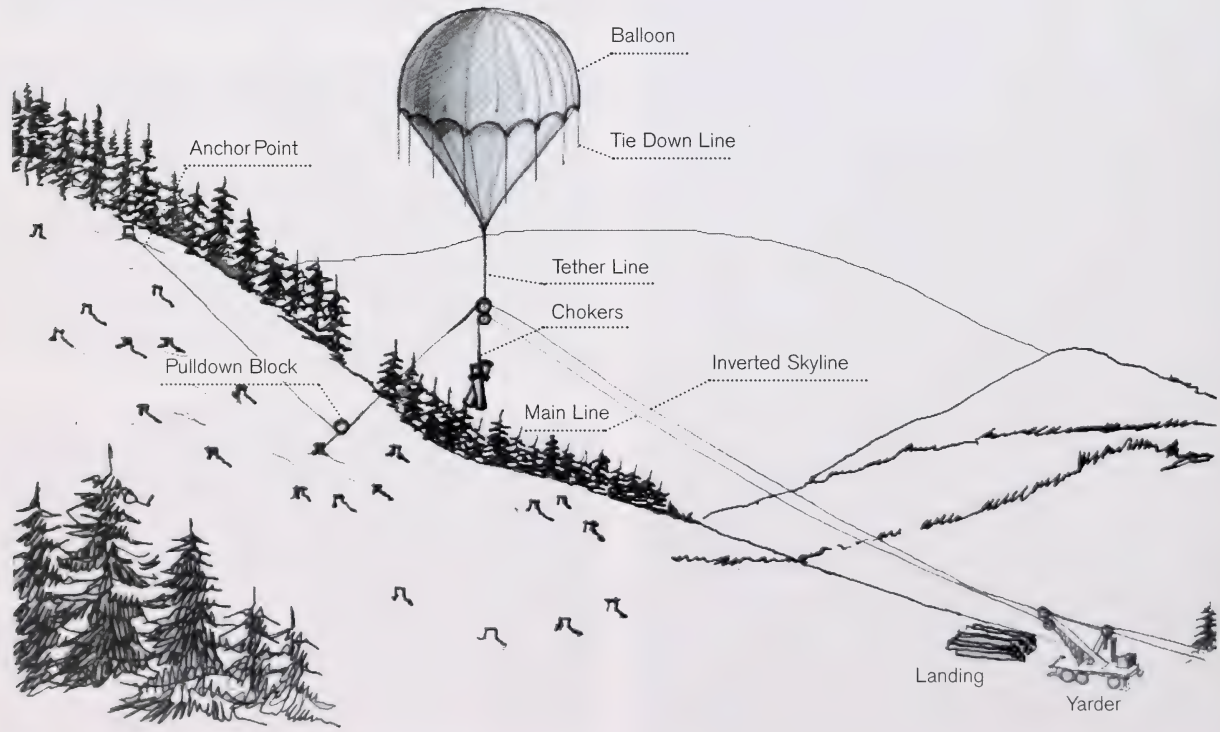
(Photos used with the permission of Crestbrook Forest Industries)

Figure 36. Running Skyline, Self Loading Truck, Bucking and Grapple Skidder



Partial cutting using a running skyline with mechanical slack pulling line for yarding through lateral corridors.
(Illustration after Cable Logging Systems by Studier and Binkley, p. 98)

Figure 37. Partial Cutting Using the Running Skyline With Mechanical Slack Pulling Line



Balloons may be used to provide lift of the main line cable.

Figure 38. Balloon Logging System – Inverted Skyline Configuration

3.1.4. AERIAL METHODS

Aerial methods, including balloon and helicopter logging, may have application in areas of high visual sensitivity or areas which have poor accessibility and must be logged for fire control or disease reasons.

3.1.4.1. BALLOON LOGGING

The balloon logging system is a modification of the skyline system using a balloon to lift the logs above the ground during the yarding operation. From the landing, tension is released from the main line cable allowing the carriage to run up slope by the balloon lift. At the loading point, the balloon is pulled down by applying tension to the skyline until the chokers reach the ground. Logs are choked and lifted above the ground by releasing tension from the skyline. The main line is used to winch the balloon down to the landing where the logs are released (refer to Figure 38).

Application for the balloon logging method

- there are no viable applications in Alberta for balloon logging at present

Limitations of the balloon logging method

- the last of the balloon logging operations in Canada stopped in the summer of 1997. This occurred because of the high amount of down time associated with a balloon logging operation.
- winds will push the balloon off to the side creating variations in cable tension and unsafe working conditions for the chokerman as the carriage, chokers and logs get pulled around by the drifting balloon
- variations in temperature will affect the balloons ability to lift
- snow and ice will shut the operation down

3.1.4.2. HELICOPTER LOGGING

Helicopter logging is a method of yarding high-value, inaccessible timber to a landing which has road access. Intensive forest management, increased demand for high quality wood, prohibitive road building costs and high visual quality objectives have driven the application of this system.

This method of timber extraction may be used in any of the silvicultural systems. The key to off-setting the cost of this type of operation is:

- a two minute turn with maximum payload;
- high-value timber on sites that are too steep or too sensitive for a conventional operation;
- prohibitive road building costs; and
- valuation of other resource values.

Trees are hand felled, limbed and bucked on site. Logs are manually choked and lifted straight up through the canopy by the helicopter. Bucking to maximize payload weight is very important (charts are available that provide information on log weight by diameter class and length per species – Forest Engineering Research Institute of Canada – Western Division (604-228-1555)). Logs are flown to a landing large enough to accommodate high daily production rates. Logs are transported to the mill with self-loading trucks.

Maximum Yarding Distance and Direction: 2,000 m down slope to landing.

Production

- depending on the machine, size of wood and length of turn, production can range from 350-650 m^3 per shift (Breadon, 1983). This ranges from 12-22 truck loads per helicopter per shift.

Advantages of helicopter logging

- the helicopter logging operation is not limited by slope
- minimal site degradation – less roads and no yarding disturbance
- advanced regeneration is left in tact due to the vertical lift of logs
- may access sites that have a zero chance of logging by conventional or cable logging methods due to sensitive soils or unstable terrain
- selective cutting systems are viable
- reduced road development cost

Disadvantages of helicopter logging

- difficult access for post harvest surveys and silvicultural treatments
- may increase surface fuel loading if trees are limbed and topped in the bush
- increased harvesting and silviculture costs
- ground crews need to be flown in and out (After Pertile, 1996)

Application of helicopter logging

- very applicable to environmentally sensitive areas. Logs are lifted straight up through the canopy ground so impact is very low and advanced regeneration is protected.
- used independently or in combination with a conventional cutblock to improve visual quality above the cutblock through selection harvest, feathered edges or complete timber removal to tree line
- removal of inaccessible timber that has been blown down or presents an insect or disease risk
- removal of high-value seed trees

3.2. REGENERATION METHODS

Regeneration or reforestation is the renewal of a forest crop by natural or artificial means. Some aspects of regeneration are part of all of the silvicultural systems previously described. However, in many cases, artificial regeneration methods are employed to speed the process of establishing regeneration. The intent is to change the naturally regenerating forest composition or to improve its quality by planting genetically-improved stock. In all cases, reforestation is a legislated requirement that is associated with a strict schedule and rigorous standards.

3.2.1. NATURAL REGENERATION

New growth may originate from within the harvested site or from trees that are immediately adjacent to it. Restocking may occur from seed or vegetatively from suckers (originating from existing root systems of cut trees) or shoots (originating from the cut stump).

Requirements for natural regeneration from seed

- a sufficient quantity of good quality seed
- sufficient mineral soil exposure
- monitoring (through regeneration surveys) for success or failure
- retreatment of any failed areas greater than 4 ha in size

Requirements for natural regeneration from coppice

- removing all or most of the overstory trees to promote enough light and heat during the next growing season to stimulate suckers and shoots
- monitoring and retreatment criteria, as above

Advantages of natural regeneration

- cheaper than artificial regeneration
- maintains local gene pool

Disadvantages of natural regeneration

- may be slower to establish
- distribution of seedling may be patchy or uneven
- no opportunity for genetic improvement
- limited ability to manipulate species composition

3.2.2. ARTIFICIAL REGENERATION

Artificial regeneration requires:

- site preparation (normally);

Figure 39. Regeneration Following Scarification and Seeding

- facilities and expertise for the collection, extraction, testing and storage of seed; and
- facilities and expertise to grow, store, transport and plant seedlings.

Advantages of artificial regeneration

- control over stocking level and distribution
- control over genetic quality of the seedlings
- control over species composition in the block

Disadvantages of artificial regeneration

- costly
- risk of damage to stock at the nursery, during storage, transportation or planting stages

3.2.3. PRE-HARVEST ASSESSMENT

The following field manuals provide procedures for pre-harvest ecological site assessment, ecosite classification and subsequent pre-harvest silvicultural prescription.

- Pre-harvest Ecological Assessment Handbook, 1996, Environmental Training Centre, Alberta Environmental Protection.

- Field Guide to Ecosites of Southwestern Alberta, 1996, J.H. Archibald, G.D. Klappstein and I.G.W. Corns.

- Forest Site Interpretation and Silvicultural Prescription Guide for Alberta, 1996, W.L. Strong and B. Carnell for the Environmental Training Centre, Alberta Environmental Protection.

The use of this pre-harvest ecological assessment and silvicultural prescription system will provide many benefits to forest management. These include:

- the linking of harvesting and reforestation;
- determining the appropriateness of logging a given site;
- choosing the appropriate season for logging;
- matching the site with the appropriate scarification method;
- flagging potential hazards or site limitations;
- reducing costs by promoting success in reforestation; and
- prime site management.

Pre-harvest ecological site assessments and silvicultural prescriptions are critical for understanding the potential opportunities and limitations associated with any site. With a better understanding of the site, forest managers can select the appropriate silvicultural system as part of the silvicultural prescription.

3.2.4. REGENERATION SITE TREATMENTS

The purpose of a regeneration site treatment is to modify existing conditions in a cutblock, by exposing mineral soil and reducing competition, in order to create a more favourable microsite for the establishment of new crop trees. Successful regeneration is a function of how the limiting factors and opportunities associated with each site have been identified from the pre-harvest ecological site assessment. Matching the regeneration site treatment with the site to solve the limiting factors is the key to successful reforestation.

Regeneration treatments may be grouped into the following categories:

- mechanical;
- chemical;
- fire; or
- no treatment.

The regeneration site treatment may influence the following microsite conditions:

- soil temperature;
- soil moisture;
- soil aeration;
- soil physical properties;
- soil nutrients;
- competing vegetation;
- frost susceptibility; and
- insect and disease susceptibility.

Readers are also referred to Section 5.9, of *Site Preparation and Stock Selection* (Strong and Carnell, 1996) which provides an operational summary of various site preparation methods and stock selection.

3.2.4.1. MECHANICAL SITE PREPARATION

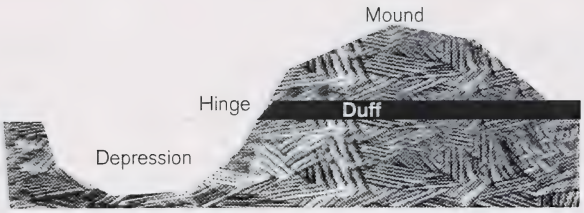
Mechanical site preparation involves mounding, scalping or mixing the surface of a cutblock to expose mineral soil. Other writers (Strong and Carnell, 1996, p. 82) describe some of the operational considerations for various types of mechanical site preparation methods.

The physical actions of a mechanical site preparation will create three types of microsites:

1. elevated microsite;
2. scalp; and
3. mixing.

Elevated microsite

The objective is to create a mound of mineral soil that is above the general soil level. These may be in the form of a discrete mound or a continuous linear strip (refer to Figure 40). Elevated microsites are created by excavators, plows or mounders. The elevated microsite provides three growing positions for seedlings.



Discrete Elevated Microsite

Continuous Elevated Microsite – Trench

Figure 40. Elevated Microsites

Depression
- higher moisture
- higher flood potential
- protection from the wind
- cooler temperature
- reduced nutrient availability – duff has been scraped away
- higher frost susceptibility

Hinge
- access to nutrients from duff layer
- reduced potential for frost and flooding
- average moisture and temperature conditions (between depression and mound)

Mound
- improved drainage – drier
- warmer
- potential for frost and flooding is further reduced
- higher exposure to sun and wind

Scalping

The objective is to create a shallow scrape to partially or completely remove the duff layer. The scalp is the intended planting site (refer to Figure 41). Scalps are created by the Bracke scarifier, drag chains, shear plow or blade. The microsite created by the scalp provides:

- reduced vegetative competition; and
- exposed mineral soil.

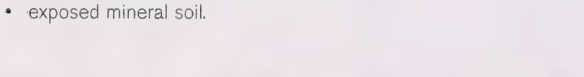


Figure 41. Scalping

Mixing

Mixing involves the mechanical integration of the surface organic layer and the top few inches of mineral soil. Mixing is achieved by a mulcher, disc trencher or shark-fin barrels and anchor chain combinations. Microsite conditions created by mixing are:

- increased nutrient cycling;
- exposed mineral soil;
- increased surface temperature; and
- breaks up competing vegetation.

3.2.4.2. CHEMICAL SITE PREPARATION

Chemical site preparation involves the use of herbicides to control competing vegetation before planting or natural regeneration and during the early stages of seedling development. Chemicals may be used to partially replicate the process of fire in a cut-over or may be used in combination with fire by killing vegetation prior to burning.

The use of chemicals has a generally low acceptance and is therefore used very little. It is generally restricted to smaller projects. A detailed knowledge of the target species (which must be susceptible to a registered and effective chemical) is required.

Conditions that favour the use of chemical site preparation

- sensitive soils – where mechanical site preparation may cause excessive damage
- cutblocks with slopes greater than 35%
- where non-chemical site treatments are ineffective in controlling the competing vegetation, e.g., stored seed (calamagrostis) may be stimulated to germinate after burning or mechanical site preparation
- where it is important to remove all of the above ground vegetation – removes shade

Chemicals may be used in combination with prescribed fire in a brown and burn or spray and burn technique. This approach may apply to a site with heavy competition and slash loads. Careful preparatory research must precede the use of chemicals in the forest environment. Extreme caution and prudence are necessary.

Brown and Burn

- uses a contact herbicide to desiccate top growth of competing vegetation
- requires burning within 2 weeks of spraying for the desired effect
- competition is frequently not killed, only desiccated
- the burn will generally be cooler and not penetrate the surface as deeply because the living roots of the competing vegetation will hold moisture
- respraying may be required if the burn is delayed

Spray and Burn

- uses a systemic herbicide to kill top growth as well as root systems of competing vegetation
- requires a minimum of 4 weeks to achieve complete root kill and stem desiccation
- burning may be delayed for several months to a year to achieve the appropriate burning window (more flexible than brown and burn)
- the burn is generally hotter and deeper as the competing vegetation is dead and dried out both above and below the surface
- with a more effective kill, the need to control re-establishing vegetation is reduced

3.2.4.3. PRESCRIBED FIRE

Many forests owe their structure, composition and distribution to natural fires. Fire is a viable site preparation tool; it can remove logging slash, reduce competition and expose mineral soil for the establishment of natural regeneration or the planting of new stock.

Prescribed fire should only be considered with a complete understanding of the natural fire regime for an area and a complete understanding of how the target species will respond to fire.

Considerations for the use of prescribed fire

- requires fairly intensive pre-planning
- potentially dangerous if the fire escapes
- can be done on steep slopes where mechanical site preparation is difficult (35% +)
- produces large plantable sites
- does not cause soil compaction or erosion channels
- costs may vary tremendously depending on conditions
- smoke pollution
- public acceptance

3.2.4.4. NO TREATMENT

No treatment is a valid decision where the conditions for natural regeneration exist. The required conditions for natural regeneration will vary depending on the type of silvicultural system that is employed.

Requirements for natural regeneration

- shade – for shade-tolerant regeneration species (Uneven-aged or shelterwood systems)
- sun – for shade-intolerant regeneration species (Even-aged systems)
- exposed mineral soil – disturbance created during the harvesting operation
- sufficient and appropriate seed source
- appropriate microsite conditions for establishment of seedlings

4. Selection of an Appropriate Silvicultural System

Silvicultural systems consist of harvesting, regeneration and stand tending components (Figure 42a). The selection of an appropriate silvicultural system must be linked to both the ecology and the long-term structural objectives of the site. In addition, multiple resource objectives from broader level plans are increasingly modifying stand level interventions. Resource management objectives from broader level plans should, as much as possible, be applied at the field level and it is important that they reflect realistic operational practices. With increased emphasis being placed on non-timber resource values, integrating strategic objectives with operational realities is becoming more challenging. It is the silviculturist's job to translate resource management objectives into stand structural objectives and to formulate a program of treatments that will promote the desired stand structure. Only when there is a clear understanding of the objectives and their structural implications can an appropriate silvicultural system be selected.

The steps in selecting a silvicultural system are outlined in Table 1. Note that management objectives from higher level plans are the departure point, followed by a careful stand and site evaluation. Silvicultural options are identified and evaluated in light of the target stand structure. The preferred system is chosen and a detailed implementation program identified.

Preliminary Data Gathering Phase	**Step 1**	Identify management objectives, standards and guidelines that must be applied from higher level plans
	Step 2	Consider the stand and site examination and collect relevant data
Option Analysis Phase	**Step 3**	Identify potential options for target stand structure
Refine Potential Options	**Step 4**	Analyze the potential options considering management objectives,standards and guidelines
	Step 5	Analyze the potential options considering damaging agents
	Step 6	Analyze the potential options considering harvesting and silvicultural logistics and costs
	Step 7	Choose the preferred target stand structure
	Step 8	Confirm the Silvicultural System

Table 1. Framework for Stand Structure Identification and Silvicultural Systems Selection

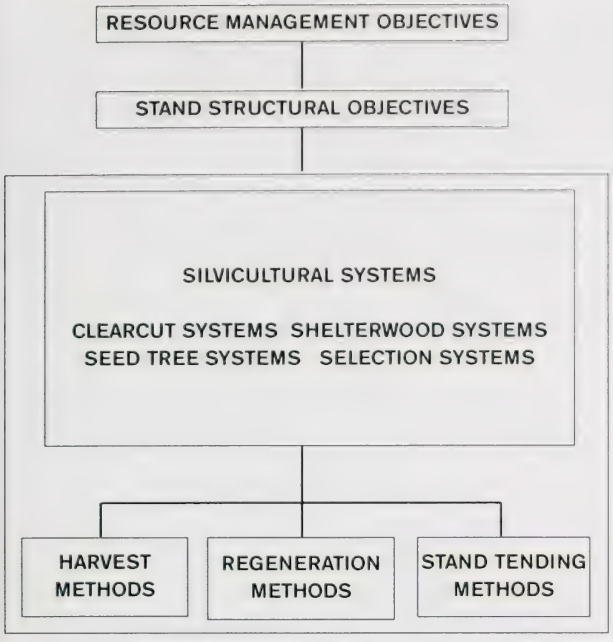


Figure 42a. Conceptual Framework for Silvicultural Systems

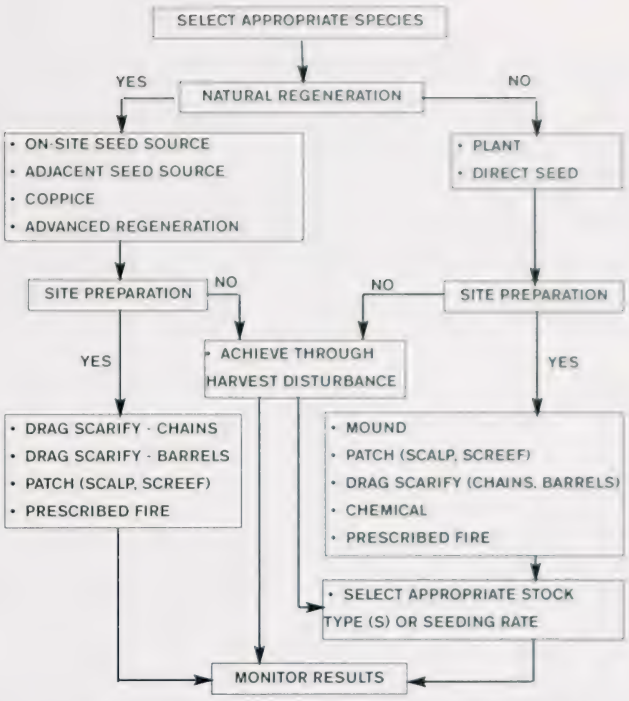


Figure 42b. Conceptual Framework for Regeneration Method Decision-Making

It is difficult to generalize regarding silvicultural systems prescriptions and their application to specific ecosystem units; management objectives are often the driving force behind the decision. "The literature shows a broad latitude in the choice of silvicultural methods that will meet the biological or ecological needs for regeneration on most sites... Ecological considerations are major constraints on selection of cutting methods on sites where environmental conditions are severe, that is, the temperature, moisture, or both are at or near the tolerance levels for tree seedlings. The objectives of the forest landowner are usually of much greater importance." (Franklin and DeBell, 1973) However, if management objectives are clearly defined, it is much easier to generalize regarding desired or target stand structures.

Table 2 shows 14 common options for stand structural design (Zielke 1997). By combining target stand structure with overstory leave-tree retention requirements and desired age class structure, a silviculturist can focus on the stand components over which he has greatest control. This will allow for developing a long-term treatment regime that will ensure that strategic management objectives are attained. The most common combinations that will be encountered in the Southern Rockies study area generally have more than one potential silvicultural system that could be applied. By thinking about target stand structures, some of the vagaries associated with silvicultural systems can be avoided.

These 14 stand structures are simplistic and they represent the more common general stand structures that can be promoted. Examples of each can be found in the silvicultural systems literature. The options presented cover the period starting with a stand regeneration harvest entry.

4.1. CRITERIA FOR SELECTING A SILVICULTURAL SYSTEM

The selection of a silvicultural system should:

- be consistent with resource management objectives of broader scale plans;
- be consistent with regional and landscape pattern objectives;
- be suitable to the ecology of the site;
- be consistent with stand-level structural objectives;
- maintain or promote forest health and site productivity;
- be considerate of fibre production and economic viability;
- consider the degree of coincidence with inherent disturbance regimes;
- ensure prompt and effective reforestation occurs and that free-to-grow targets can be met;
- account for visual values;
- consider the effect on forest protection (fire, insects and disease);
- consider the impacts on other resources (recreation, range, soils, water, etc.);
- consider and be consistent with wildlife habitat management objectives;
- consider maximum use of existing road infrastructure (minimize road densities where possible);
- consider age-class distribution;
- account for patch size, shape, position and residual cutblock structure;
- consider landscape connectivity; and
- consider species composition and distribution.

Cutting Patterns	Overstory Leave-Tree Retention	Age Class Structure	Silvicultural Systems
1. Overstory Removal or Clearcutting	none	even-aged[1]	- clearcut - natural shelterwood
2. Uniform Leave-trees	short-term[2]	even-aged	- uniform seed tree - uniform shelterwood - uniform nurse-tree shelterwood
3. Uniform Leave-trees	long-term[3]	even-aged	- clearcut with uniform reserves[4] - uniform seed tree with reserves - uniform shelterwood with reserves - nurse-tree shelterwood with reserves - irregular shelterwood with or without reserves - natural shelterwood with uniform reserves
4. Uniform Leave-trees	long-term	uneven-aged[5]	- single-tree selection - single-tree selection with reserves
5. Leave-tree Groups[6]	short-term	even-aged	- group seed tree
6. Leave-tree Groups	long-term	even-aged	- clearcut with group reserves - group seed tree with reserves - natural shelterwood with group reserves
7. Group Removal	short-term	even-aged	- group shelterwood - group nurse-tree shelterwood
8. Group Removal	long-term	even-aged	- group shelterwood with reserves
9. Group Removal	long-term	uneven-aged	- group selection - group selection with reserves
10. Strip Removal (only)	short-term	even-aged	- strip clearcut
11. Strip Removal (only)	long-term	uneven-aged	- strip selection[7]
12. Strip Removal (with uniform leave-trees)	short-term	even-aged	- strip shelterwood
13. Strip Removal (with uniform leave-trees)	long-term	even-aged	- strip shelterwood with reserves
14. Strip Removal (with uniform leave-trees)	long-term	even-aged	- strip selection with reserves

1. one or two age classes
2. during the regeneration period (the first 20 years of the rotation)
3. after the regeneration period and often for the entire rotation
4. can be left in a uniform, grouped or strip fashion
5. three or more well represented vigorous age classes which appear as multiple verticle layers, uniformly distributed or clumped
6. resulting in openings that are small enough to have different (more moderate) micro-climate relative to a clearcut
7. strips are narrow enough to have different (more moderate) micro-climate relative to a clearcut

Table 2. Common Options for Stand Structural Design

4.2. SELECTING A HARVEST METHOD

There is a wide array of harvest method choices and it is not possible to assign one of them based solely on ecological classification criteria. However, some of the criteria that help define ecosystem units will also be important when considering the harvest method that is most appropriate for a site. Each site is unique and requires its own pre-harvest ecological assessment and prescription. The selection of a harvest (extraction) method is part of the prescription and must be based on a specific evaluation of the site. Only then can the potential limitations and opportunities presented at the site be properly managed.

There are a number of operational considerations that will weigh heavily on the final decision (Table 3). There are other factors that are not considered in Table 3 that also have a strong influence on the final choice of a harvesting method. Some of these include the contractor and equipment mix that is available to choose from, minimum required production rates, the skill and commitment of the operators and operator safety.

The selection of a harvest (extraction) method should:

- be consistent with the landscape pattern objectives for the area;
- be compatible with the stand management objectives and the structural objectives for that site;
- be consistent with the ecological site assessment and pre-harvest silvicultural prescription, taking into account excess moisture, seasonal operability, rutting and compaction hazard, slope percent and proximity to streams;
- be consistent with the visual values for the area;
- be consistent with the wildlife habitat values for the area;
- be economically and operationally feasible;
- not damage the site or its soil;
- consider the best opportunities for successful, low-cost reforestation; and
- take into account future resource development plans for the area to maximize the value and use of high-cost road systems.

4.3. LINKING TREATMENT REGIMES TO ECOLOGICAL SITE TYPES

Through the pre-harvest ecological site assessment, the silviculturist should determine the potential limitations and opportunities for a given site. Silvicultural systems must be matched to the ecological site types. An interpretive reclassification of the ecosite phases present in the study area was carried out in order to match potential treatment types to the opportunities and constraints of the various site types. This approach assists in tying the strategic planning process to field operations as many of the regional and landscape pattern objectives are related to ecosite phase.

4.3.1. INTERPRETIVE CLASSIFICATIONS

Some of the objectives for the ecosite classification system for Alberta are to:

- facilitate the application of ecological information to decisions on a wide variety of activities within the realm of forest resource management;
- facilitate the collection and organization of information to expedite the development of resource management applications and decision support systems; and
- provide a common basis for integrated planning (Archibald, et. al., 1996).

One of the ways to promote these objectives is to develop interpretive classifications for models that use ecological and site variables. Three interpretive classifications have been developed for the Southern Rockies study area and are presented in Tables 5, 6 and 7.

1. Ecosites, ecosite phases or plant community types that are expected to react similarly to specific management treatments or treatment regimes have been grouped to provide a classification of stand regeneration regimes.
2. A model for choosing a site preparation treatment has been developed using site and ecological variables.
3. A model for assessing possible harvest methods has been developed using site and ecological variables.

4.3.2. REGENERATION TACTICS

There are several regeneration tactics or treatment regimes (Table 4) that are applicable in the Southern Rockies study area.

Natural Regeneration, Regime 1 (Nat 1) – Leave for Natural (seed)
Prescribed for dry to very dry lodgepole pine dominated sites with thin duff layers. If the P1 component is low, there may be a need to augment on-site seed with direct seeding. Season of harvest on these sites will not influence the choice of treatment regimes. Processing at the stump should be considered to ensure sufficient well distributed cones.

Natural Regeneration, Regime 2 (Nat 2) – Site Prepare for Natural
Prescribed for winter logging in dry to moist lodgepole pine dominated sites with thin to moderate duff layers. Summer logging may also require this regime in some cases. If the pine component is low, there may be a need to augment on-site seed with direct seeding. Processing at the stump should be considered to ensure sufficient well distributed cones.

Natural Regeneration, Regime 3 (Nat 3) – Site Prepare for Natural (seed)
Prescribed for partial cutting silvicultural systems that will promote conditions that are favourable for natural regeneration from overstory or adjacent stand seed sources.

Table 3. Generalized Site Preparation Treatment Guidelines

LEGEND
+ good (no limitations)
0 fair (some limitations)
- poor (significant limitations)

			Slope			Moisture Regime			Nutrient Regime			Slash Loading			Duff Depth (cm)			Competition			Cold Soils	unfavorable substrate < 30 cm	High Coarse Fragments > 60%	Erosion Potential	Valuable Understory
			0 – 25%	25 – 40%	40% +	Dry (1 – 3)	Moist (4 – 6)	Wet (7 – 9)	Poor (a – b)	Medium (c)	Rich (d – e)	Light	Medium	Heavy	<= 5 cm	6 – 20 cm	21+ cm	Deciduous Trees	Shrubs	Grass/Forbs					
Mechanical	Mound	large	+	0	-	-	-	+	-	0	+	+	0	-	-	0/+	+	0	+	+	+	-	-	0/+	0
		small	+	0	-	-	+	0	0/-	+	+/0	+	0	-	0	+	-	-	+	0/+	+	0	-	+	0/-
		continuous	+	-	-	-	0	0	-	0	0	+	0	-	-	0/-	+	-	0	0	+	-	-	-	-
	Scalp	excavator	+	+	0	0	+	+/0	0/+	+	0	+	0	0	0	+	0	-/0	0/+	+/0	0	+	0	+	0
		bracke	+	0	-	+	+	-0/-	+	+	0/-	+	0	-	+	+/0	-	-	-/0	-	-	+	0	+	/-
		drag – chains	+	0	-	+	+/0	-	+	+	-	+	0	-	+	+	-	-	0	-	-	+	+	0	-
		drag – barrels	+	0	-	+	+	-	+	+	-	+	0	-	0	+	0	-	0	0	-	+	0	0	-
		brush rake	+	0/-	-	-	+	-	-	0	+	0	0	0	0/-	+	0	0/+	0/+	-	0	0	0/-	-	-
		shear plow	+	-	-	-	0	0	0	+	0/+	+	0	0	0	+	+	0	-/0	-	-	0	+	0	-
	Mix	bedding plow	+	-	-	-	+	0	-	+	+	+	0/-	-	+	+	-	+	+	+	+	0	-	0	-
		VH Mulcher	+	+	0	+	+	0	0	+	+	+	0	0	+	+	0	0	0	0	0	0	-	+	0
		trencher	+	0	-	+	+	0	+	+	0	+	0	-	+	+	-	-	0	0/+	0/+	0	0	0	0/-
Chemical			+	+	-	+	+	+	+	+	+	+	+	+	+	0	-	+	+	+	-	+	+	+	+
Fire			+	+	+	-/0	+	0	0/-	+	-/-0	0/-	0	0	0	0/-	-	0	+	0	0	+	+	+	-
No Treatment			+	+	0	+	0	-	+	0	-	+	+	0	+	0	-	-	-	-/0	-	+	+	+	+

NOTES:
- Interpretation is required in some cases. For example, where significantly different competing species belong to the same broad grouping, different results should be anticipated (e.g., pine grass vs. Marsh reed grass).
- The experience and skill of the equipment operator will significantly impact the appropriateness of a site preparation prescription.
- Unfavourable substrates referred to include heavy Bt, pure sands, fragmental layers and bedrock.

Regime	Regen. Method	Regen. Tactic	Seed Source	Site Prep. Method	Comments
nat 1	Natural	leave for natural (seed)	on-site*	through harvest activities	may augment with artificial seeding
nat 2	Natural	site prep. for natural	on-site*	drag scarify	may augment with artificial seeding
nat 3	Natural	leave for natural (seed)	overstory	various	partial cutting silvicultural systems
nat 4	Natural	leave for natural (coppice)	coppice	none	Aw stands
art 1	Artificial	site prep. and artificial seed	artificial seeding	drag, patch or blade scarify	anticipate minor natural fill-in
art 2	Artificial	site prep. for plant	seedlings	various	planting
art 3	Artificial	no site prep. and plant	seedlings	through harvest activities	raw planting

* slash-borne cones from lodgepole pine

Table 4. Proposed Treatment Regimes for the Southern Rockies Project Area

Natural Regeneration, Regime 4 (Nat 4) – Leave for Natural (coppice)
Not prescribed for the C5 Management Unit because aspen is currently not being harvested commercially. May be applicable in the future for non-commercial applications.

Artificial Regeneration, Regime 1 (Art 1) – Site Prepare and Artificial Seed
Site preparation treatments should target sufficient disturbance to promote seedling establishment while minimizing the removal of the forest floor and coarse woody debris.

Artificial Regeneration, Regime 2 (Art 2) – Site Prepare for Planting
Site preparation treatments should target sufficient disturbance to promote planter access and seedling establishment while minimizing the removal of the forest floor and coarse woody debris.

Artificial Regeneration, Regime 3 (Art 3) – No Site Preparation and Plant
Planters should focus on microsite selection to promote seedling establishment and growth.

The selection of the appropriate reforestation tactic is dependent on the silvicultural system chosen and the long-term management objectives for the site. Generally, early seral species are easier to establish and will grow more vigorously than mid to late seral species will. Growth rates of early seral species will outstrip those of mid to late seral species for 30-50 years. After that, their growth rates decline and mid to late seral species will catch up and may even pass the total height growth of the early seral species. The issues include time to reach free-growing and projected rotation length.

Also, some of the early seral species, lodgepole pine in particular, are susceptible to a wide range of insects and diseases that do not become a significant concern until ages greater than 12. All of these issues need to be factored into the selection of a regeneration tactic.

4.3.3. STAND REGENERATION TREATMENTS

Figure 42b provides a generalized framework for considering stand regeneration treatments and it was used for developing the first approximation of a stand regeneration classification for the Southern Rockies study area. Proposed treatment categories follow established theory, terminology and operational practice (e.g., Strong and Carnell, 1996).

Seven generalized management regimes are proposed for the C5 management unit (Table 4). They correspond to the provincial regeneration tactics and additional information is provided to clarify the treatment regimes. Tables 5 and 6 provide treatment regimes information by Natural Subregion.

4.3.4. SITE PREPARATION TREATMENTS

There are a number of site preparation choices and it is not possible to assign one of them based solely on ecological classification criteria. Many of the criteria that define ecosystem units will also be important when considering the type of site preparation that is most appropriate for a site. However, there are a number of operational considerations that will weigh heavily on the final site preparation treatment decision.

Table 3 provides general criteria that can be used to assist a field practitioner in determining which site preparation treatments may be appropriate for a particular site. All factors must be weighed against each other before a final decision can be reached because it is possible that one negative factor may be significant enough to exclude an option. Also, the table provides a generalized overview of the important factors, but care must be taken in prescribing the application of a particular treatment on a specific site. Table 3 does not provide an exhaustive list of all available site preparation equipment and includes some that would not be appropriate in the study area (e.g., the Martinni Plow).

Table 3. Proposed treatment regimes for the Montaine Natural Subregion, sorted by plant community type

Ecosite Phase			Plant Community Type		Treatment Regime: Primary[8]	Treatment Regime: Acceptable[9]	Limiting Factors	Comments
a1	limber pine/juniper	Fd-Pf	a1.1	Fd-Pf/juniper	non-merch	non-merch	very dry, nutrient poor, shallow to bedrock	open, poor quality stands, low volumes, sensitive to site preparation treatments, leave as in-block reserves
b1	bearberry	Pl	b1.1	Pl/bearberry-juniper	nat 1	art 1	very dry, nutrient poor, thin duff	minimize forest floor displacement
b2	bearberry	Aw	b2.1	Aw/bearberry	non-merch	non-merch	very dry, nutrient poor-medium, thin duff	aspen stands
b3	bearberry	Aw-Sw-Pl	b3.1	Aw-Sw-Pl/bearberry	non-merch	non-merch	dry, thin-moderate duff, aspen competition	mixed decid./conif. stands, may be non-merch
c1	Canada buffalo-berry/hairy wildrye	Fd	c1.1	Fd/needle litter	nat 3	art 1*, art 3*	dry, thin-moderate duff	minimize forest floor displacement
			c1.2	Fd/hairy wildrye	nat 3	art 1*, art 3*	dry, thin-moderate duff	minimize forest floor displacement
c2	Canada buffalo-berry/hairy wildrye	Pl	c2.1	Pl/Canada buffalo-berry/hairy wildrye	nat 3	nat 1	dry, thin-moderate duff	minimize forest floor displacement
c3	Canada buffalo-berry/hairy wildrye	Aw	c3.1	Aw/hairy wildrye	non-merch	non-merch	dry	aspen stands
c4	Canada buffalo-berry/hairy wildrye	Aw-Sw-Pl-Fd	c4.1	Aw-Sw-Pl-Fd/hairy wildrye	art 3	art 2, nat 2	dry, thin-moderate duff	mixed decid./conif. stands
d1	creeping mahonia-white meadowsweet	Fd	d1.1	Fd/feather moss	nat 3	art 1, art 3	dry, thin-moderate duff, some steep slopes	minimize forest floor displacement, heavy pinegrass after 3 years
			d1.2	Fd/white meadowsweet	nat 3	art 1, art 3	dry, thin-moderate duff, some steep slopes	minimize forest floor displacement
d2	creeping mahonia-white meadowsweet	Pl	d2.1	Pl/green alder	nat 2	art 1, art 2	dry, thin-moderate duff	
			d2.2	Pl/creeping mahonia-white meadowsweet	nat 2	art 2, art 2	dry, thin-moderate duff	
			d2.3	Pl/pinegrass	nat 2	art 1, art 2	dry, thin-moderate duff	heavy pine grass competition after 3 years
			d2.4	Pl/mountain lover/bear grass	nat 2	art 1, art 2	dry, thin-moderate duff	
			d2.5	Pl/feather moss	nat 2	art 1, art 2	dry, thin-moderate duff	
d3	creeping mahonia-white meadowsweet	Sw	d3.1	Sw/feather moss	art 3 (2)	art 1	cool soils, invasion by forbs	
e1	thimbleberry/pinegrass	Pl	e1.1	Pl/thimbleberry	nat 2	art 2 (3)	thin-moderate duff, brush competition	nutrient rich/subhygric sites may not regenerate naturally
e2	thimbleberry/pinegrass	Aw	e2.1	Aw/thimbleberry	art 2**	art 3	grass, shrub and aspen competition	mixed decid./conif. stands, may be non-merch
			e2.2	Aw/pinegrass	art 2**	art 3	grass, shrub and aspen competition	mixed decid./conif. stands, may be non-merch
			e2.3	Aw/saskatoon-snowberry	art 2**	art 3	grass, shrub and aspen competition	mixed decid./conif. stands, may be non-merch
e3	thimbleberry/pinegrass	Sw	e3.1	Sw/thimbleberry	art 2	art 3	thin-moderate duff, brush competition	competition develops quickly
f1	balsam poplar	Pb	f1.1	Pb/snowberry - f2.1 Sw-Pb[10]	art 2	art 3	thin-moderate duff, brush competition	competition develops quickly, small inclusions in blocks
g1	horsetail	Sw-Pb	g1.1	Sw-Pb/horsetail	art 2	art 3	cool-wet soils, competition	competition develops quickly, small inclusions in blocks
g2	horsetail	Sw-Pb	g2.1	Sw-Pb/horsetail	art 2	art 3	cool-wet soils, competition	competition develops quickly, small inclusions in blocks
			g2.2	Sw-Pb/dogwood	art 2	art 3	cool-wet soils, competition	competition develops quickly, small inclusions in blocks

NOTE: 1. Soil displacement and soil compaction shoud be minimized on all sites during harvesting and regeneration treatments. This will help to conserve nutrients and reduce the potential for soil erosion.

2. Soil moisture deficit and seasonal drought can be significant limiting factors throughout the ecosystems in the Montane Natural Subregion except on the f and g sites. This can be confounded by Chinook wind conditions.

[8] Primary treatment regimes are designed to promote managed stands with similar species composition to the natural stand.

[9] Acceptable treatment regimes promote in acceptably stocked and free-growing stands and may result in species conversion.

* Species conversion to lodgepole pine will result.

** Manage for conifers (primarily Sw).

[10] This plant community type does not appear in the field guide for southwestern Alberta. Plant species are the same as in the f1.1, Sw dominates in the overstory.

Table 6. Proposed Treatment Regimes for the Subalpine Natural Subregion, sorted by plant community type

Ecosite Phase			Plant Community Type		Treatment Regime		Limiting Factors	Comments
					Primary[11]	Acceptable[12]		
a1	lichen	Pl	a1.1	Pl/juniper/lichen	non-merch	art 1, nat 1	very dry, nutrient poor, shallow to bedrock	open, poor quality/low volume stands, small inclusions in blocks, manage as in-block reserves
b1	bearberry/hairy wildrye	Pl	b1.1	Pl/bearberry/hairy wildrye	nat 1	art 1	very dry, nutrient poor, thin duff	minimize forest floor displacement, high elevation, short growing season
b2	bearberry/hairy wildrye	Se	b2.1	Se/bearberry/hairy wildrye[13]	art 1*	art 3*	very dry, nutrient poor, thin duff	minimize forest floor displacement
c1	subalpine larch/heather	La-Fa	c1.1	La-Fa/heather-grouseberry	non-merch	non-merch	dry, thin duff	small inclusions in blocks, manage as in-block resrves
d1	spruce/heather	Se	d1.1	Se/heather	non-merch	art 3, art 1	dry, thin duff	open, low volume stands, min. forest floor displacement, very difficult regen. chance, manage as in-block reserves
e1[14]	false azalea-grouse-berry	Pl	e1.1	Pl/green alder/arnica	nat 2	art 3, art 2	dry-wet, thin-moderate duff	mimimize forest floor displacement
			e1.2	Pl/grouse-berry/feather moss	nat 2	art 3, art 2	dry-wet, thin-moderate duff	minimize forest floor displacement
			e1.3	Pl/low bilberry	nat 2	art 3, art 2	dry-wet, thin-moderate duff	minimize forest floor displacement
			e1.4	Pl/false azalea/feather moss	nat 2	art 2, art 3	dry-wet, thin-moderate duff, competition	min. forest floor displacement, ericaceous shrub complex
			e1.5	Pl/pinegrass	nat 2	art 3, art 2	dry-wet, thin-moderate duff	minimize forest floor displacement, pine grass complex
			e1.6	Pl/Canada Buffalo-berry	nat 2	art 3, art 2	dry-wet, thin-moderate duff	minimize forest floor displacement
e2	false azalea-grouse-berry	Pw	e2.1	Pw/false azalea	art 2	art 1*	dry, thin-moderate duff, competition	min. forest floor displacement, ericaceous shrub complex, high elevation, short growing season
e3	false azalea-grouse-berry	Se	e3.1	Se/grouse-berry/feather moss	art 2	art 1*	moist, thin-moderate duff	minimize forest floor displacement
			e3.2	Se/low bilberry/feather moss	art 2	art 1*	moist, thin-moderate duff	minimize forest floor displacement
			e3.3	Se/green alder/feather moss	art 2	art 1*	moist, thin-moderate duff	minimize forest floor displacement
			e3.4	Se/false azalea/feather moss	art 2	art 1*	moist, thin-moderate duff, competition	min. forest floor displacement, ericaceous shrub complex
			e3.5	Se/Canada buffalo-berry/feather moss	art 2	art 1*	moist, thin-moderate duff	minimize forest floor displacement
			e3.6	Se/stair-step moss	art 2	art 1*	moist, thin-moderate duff	minimize forest floor displacement
			e3.7	Se/wiry fern moss	art 2	art 1*	moist, thin-moderate duff	minimize forest floor displacement
e4	false azalea-grouse-berry	Fa	e4.1	Fa/grouse-berry, feather moss	art 2	art 1*	moist, thin-moderate duff	minimize forest floor displacement
			e4.2	Fa/false azalea/feather moss	art 2	art 1*	moist, thin-moderate duff, competition	min. forest floor displacement, ericaceous shrub complex
f1	thimbleberry	Pl	f1.1	Pl/thimbleberry	nat 2	art 2, art 3	thin-moderate duff, brush competition	nutrient rich/subhygnc sites may not regenerate naturally
f2	thimbleberry	Fa-Se	f2.1	Fa-Se/thimbleberry	art 2	art 3	thin-moderate duff, brush competition	competition develops quickly
g1	dwarf birch/tufted hair grass		g1.1	dwarf birch/tufted hair grass	non-forest	non-forest		non-forest sites
h1	horsetail	Se	h1.1	Se/horsetail/feather moss	art 2	art 3	cold-wet soils	competition develops quickly, small inclusions in blocks
h2	horsetail	fen	h2.1	fen/dwarf birch/sedge/golden moss	non-forest	non-forest		non-forest sites

NOTE 1. Soil displacement and soil compaction shoud be minimized on all sites during harvesting and regeneration treatments. This will help to conserve nutrients and reduce the potential for soil erosion.

2. Soil moisture deficit and seasonal drought can be significant limiting factors throughout the ecosystems in the Subalpine Natural Subregion except on the f and g sites. This can be confounded by Chinook wind conditions.

[11] Primary treatment regimes are designed to promote managed stands with similar species composition to the natural stand

[12] Acceptable treatment regimes promote in acceptably stocked and free-growing stands and may result in species conversion

* Species conversion to lodgepole pine will result

[13] This plant community type does not appear in the field guide for southwestern Alberta. Plant species are the same as in the b1.1, Sw dominates in the overstory.

[14] These ecosite phase occupy a wide range of ecological moisture and nutrient regimes. Artificial reforestation may be required in the moist-wet, nutrient rich sites

Table 7. Plant Community Types of the C5 Management Unit, sorted by primary treatment regime

NSR	Ecosite Phase			Plant Community Type		Treatment Regime	
						Primary	Acceptable
SA	g1	dwarf birch/tufted hair grass		g1.1	dwarf birch/tufted hair grass	non-forest	non-forest
SA	h2	horsetail	fen	h2.1	dwarf birch/sedge/golden moss	non-forest	non-forest
SA	b2	bearberry/hairy wildrye	Se	b2.1	Se/bearberry/hairy wildrye	art 1	art 3
MN	e2	thimbleberry/pinegrass	Aw	e2.1	Aw/thimbleberry	art 2	
MN	e3	thimbleberry/pinegrass	Aw	e2.2	Aw/pinegrass	art 2	
MN	e4	thimbleberry/pinegrass	Aw	e2.3	Aw/saskatoon-snowberry	art 2	
MN	e3	thimbleberry/pinegrass	Sw	e3.1	Sw/thimbleberry	art 2	art 3
MN	f1	balsam poplar	Pb	f1.1	Pb/snowberry	art 2	
MN	g1	horsetail	Sw-Pb	g1.1	Sw-Pb/horsetail	art 2	
MN	g2	horsetail	Sw-Pb	g2.1	Sw/horsetail	art 2	
MN	g3	horsetail	Sw-Pb	g2.2	Sw/dogwood	art 2	
SA	e2	false azalea-grouse-berry	Pw	e2.1	Pw/false azalea	art 2	art 1
SA	e3	false azalea-grouse-berry	Se	e3.1	Se/grouse-berry/feather moss	art 2	art 1
SA	e4	false azalea-grouse-berry	Se	e3.2	Se/low bilberry/feather moss	art 2	art 1
SA	e5	false azalea-grouse-berry	Se	e3.3	Se/green alder/feather moss	art 2	art 1
SA	e6	false azalea-grouse-berry	Se	e3.4	Se/false azalea/feather moss	art 2	art 1
SA	e7	false azalea-grouse-berry	Se	e3.5	Se/Canada buffalo-berry/feather moss	art 2	art 1
SA	e8	false azalea-grouse-berry	Se	e3.6	Se/stair-step moss	art 2	art 1
SA	e9	false azalea-grouse-berry	Se	e3.7	Se/wiry fern moss	art 2	art 1
SA	e4	false azalea-grouse-berry	Fa	e4.1	Fa/grouse-berry/feather moss	art 2	art 1
SA	e5	false azalea-grouse-berry	Fa	e4.2	Fa/false azalea/feather moss	art 2	art 1
SA	f2	thimbleberry	Fa-Se	f2.1	Fa-Se/thimbleberry	art 2	art 3
SA	h1	horsetail	Se	h1.1	Se/horsetail/feather moss	art 2	
MN	c4	Canada buffalo-berry/hairy wildrye	Aw-Sw-Pl-Fd	c4.1	Aw-Sw-Pl-Fd/hairy wildrye	art 3	art 2, nat 2
MN	d3	creeping mahonia-white meadowsweet	Sw	d3.1	Sw/feather moss	art 3 (2)	art 1
MN	b1	bearberry	Pl	b1.1	Pl/bearberry-juniper	nat 1	art 1
SA	b1	bearberry/hairy wildrye	Pl	b1.1	Pl/bearberry/hairy wildrye	nat 1	art 1
MN	c2	Canada buffalo-berry/hairy wildrye	Pl	c2.1	Pl/Canada buffalo-berry/hairy wildrye	nat 2	nat 1
MN	d2	creeping mahonia-white meadowsweet	Pl	d2.1	Pl/green alder	nat 2	art 1, art 2
MN	d3	creeping mahonia-white meadowsweet	Pl	d2.2	Pl/creeping mahonia-white meadowsweet	nat 2	art 1, art 2
MN	d4	creeping mahonia-white meadowsweet	Pl	d2.3	Pl/pinegrass	nat 2	art 1, art 2
MN	d5	creeping mahonia-white meadowsweet	Pl	d2.4	Pl/mountain lover/bear grass	nat 2	art 1, art 2
MN	d6	creeping mahonia-white meadowsweet	Pl	d2.5	Pl/feather moss	nat 2	art 1, art 2
MN	e1	thimbleberry/pinegrass	Pl	e1.1	Pl/thimbleberry	nat 2	art 2 (3)
SA	e1	false azalea-grouse-berry	Pl	e1.1	Pl/green alder/arnica	nat 2	art 3, art 2
SA	e2	false azalea-grouse-berry	Pl	e1.2	Pl/grouse-berry/feather moss	nat 2	art 3, art 2
SA	e3	false azalea-grouse-berry	Pl	e1.3	Pl/low bilberry	nat 2	art 3, art 2
SA	e4	false azalea-grouse-berry	Pl	e1.4	Pl/false azalea/feather moss	nat 2	art 2, art 3
SA	e5	false azalea-grouse-berry	Pl	e1.5	Pl/pinegrass	nat 2	art 3, art 2
SA	e6	false azalea-grouse-berry	Pl	e1.6	Pl/Canada buffalo-berry	nat 2	art 3, art 2
SA	f1	thimbleberry	Pl	f1.1	Pl/thimbleberry	nat 2	art 2, art 3
MN	c1	Canada buffalo-berry/hairy wildrye	Fd	c1.1	Fd/needle litter	nat 3	art 1, art 3
MN	c2	Canada buffalo-berry/hairy wildrye	Fd	c1.2	Fd/hairy wildrye	nat 3	art 1, art 3
MN	d1	creeping mahonia-white meadowsweet	Fd	d1.1	Fd/feather moss	nat 3	art 1, art 3
MN	d2	creeping mahonia-white meadowsweet	Fd	d1.2	Fd/white meadowsweet	nat 3	art 1, art 3
MN	a1	limber pine/juniper	Fd-Pf	a1.1	Fd-Pf/juniper	non-merch	non-merch
MN	b2	bearberry	Aw	b2.1	Aw/bearberry	non-merch	non-merch
MN	b3	bearberry	Aw-Sw-Pl	b3.1	Aw-Sw-Pl/bearberry	non-merch	non-merch
MN	c3	Canada buffalo-berry/hairy wildrye	Aw	c3.1	Aw/hairy wildrye	non-merch	non-merch
SA	a1	lichen	Pl	a1.1	Pl/juniper/lichen	non-merch	art 1, nat 1
SA	c1	subalpine larch/heather	La-Fa	c1.1	La-Fa/heather-grouseberry	non-merch	non-merch
SA	d1	spruce/heather	Se	d1.1	Se/heather	non-merch	art 3, art 1

5. Integrating Resource Management Objectives

Silviculture is a powerful tool for the achievement of integrated forest management objectives. Requirements for biological diversity, habitat for species of concern, water quality, visual resource protection and other forest values are all potentially affected by silvicultural interventions. Decisions taken at the stand level can influence many broader scale processes and managers should be aware of the potential implications and opportunities that various silvicultural systems afford. Silvicultural decisions should support broader level plans which provide direction to overall landscape pattern and configuration, species composition, age class distribution, wildlife species requirement, etc. Silvicultural systems, as the integrator of stand structure and stand level treatments, can be used as the process for ensuring that broader scale multiple resource objectives are supported over the life of a stand (rotation).

The following sections identify broader scale landscape transformation considerations as well as providing examples for provision of internal block structure and other habitat requirements for specific species of wildlife. Opportunities for addressing visual quality concerns are also reviewed. None of the following sections should be viewed as either prescriptive or exhaustive but rather, are included to increase awareness of potential silvicultural implications in these areas.

5.1. FOREST LANDSCAPE PATTERN, TRANSFORMATION AND CUTBLOCK CONFIGURATION

The relationship between pattern and process has been a focus of many ecological studies (Wallin et. al., 1994, Turner, 1989, Borman and Likens, 1979). Flows and distributions of fire, water, nutrients, species, fibre and forage are closely tied to the spatial patterns of the landscape. These landscape patterns are produced and maintained by disturbance and recovery dynamics and controlled by climactic, physiographic and biotic conditions and processes.

Understanding and characterizing the heterogeneity produced by inherent disturbance regimes is an important step in developing pattern objectives for both regions and landscapes. A knowledge of the historical conditions is important in order to evaluate the sustainability of current and potential landscape patterns. As current forest management involves a high level of uncertainty, it is prudent to manage within the range of variability that has already occurred in the landscape. In the absence of certainty, historical patterns of heterogeneity should be followed or, at the very least, understood and acknowledged in order to reduce the risk of losing biodiversity and disrupting ecological processes (Turner et. al.,1994).

Animals, plants, air, water, soil, fire and people flow across the landscape through a mosaic of different patch types. The landscape pattern is largely determined by the type, size, shape and position of different patches of local ecosystems (i.e., individual stands). Other than fire, forestry operations are the major determinant of landscape pattern in the managed forest. Pattern must always be considered in the broader context and foresters must avoid consideration of individual patches in isolation of their overall configuration within the landscape. Details of

landscape pattern objectives that are specific to individual landscapes within the study area are provided elsewhere. However, there are several conceptual models of land transformation sequences that are directly applicable to forestry.

Cutting of forested lands generally occurs in one of the following land transformation sequence models.

Edge – cutting progressively from an edge.
Corridor – cutting outward from a central cut strip (may be multiple strips).
Nucleus – cutting outward from a central point.
Nuclei – cutting outward from several points.
Dispersed – cuts that avoid adjacent cuts until later in the rotation may be alternate patch.

Conceptual sequences including a random model for comparison are illustrated below.

These configurations accommodate, to a greater or lesser degree, what Forman (1995) has called indispensible priority components for whole landscapes.

He cites several "indispensibles" which cannot be substituted by other components and are critical to a well functioning landscape. These include:

- a few large natural vegetation patches;
- wide well vegetated corridors protecting water courses;
- connectivity for movement of key species among large patches; and
- heterogeneous bits of natural vegetation scattered across the human transformed forest in the form of "stepping stone" islands and corridors.

As large patches and connectivity are key components, an important aspect of forest landscape management is to reduce the shrinkage, perforation, dissection and fragmentation of large well connected

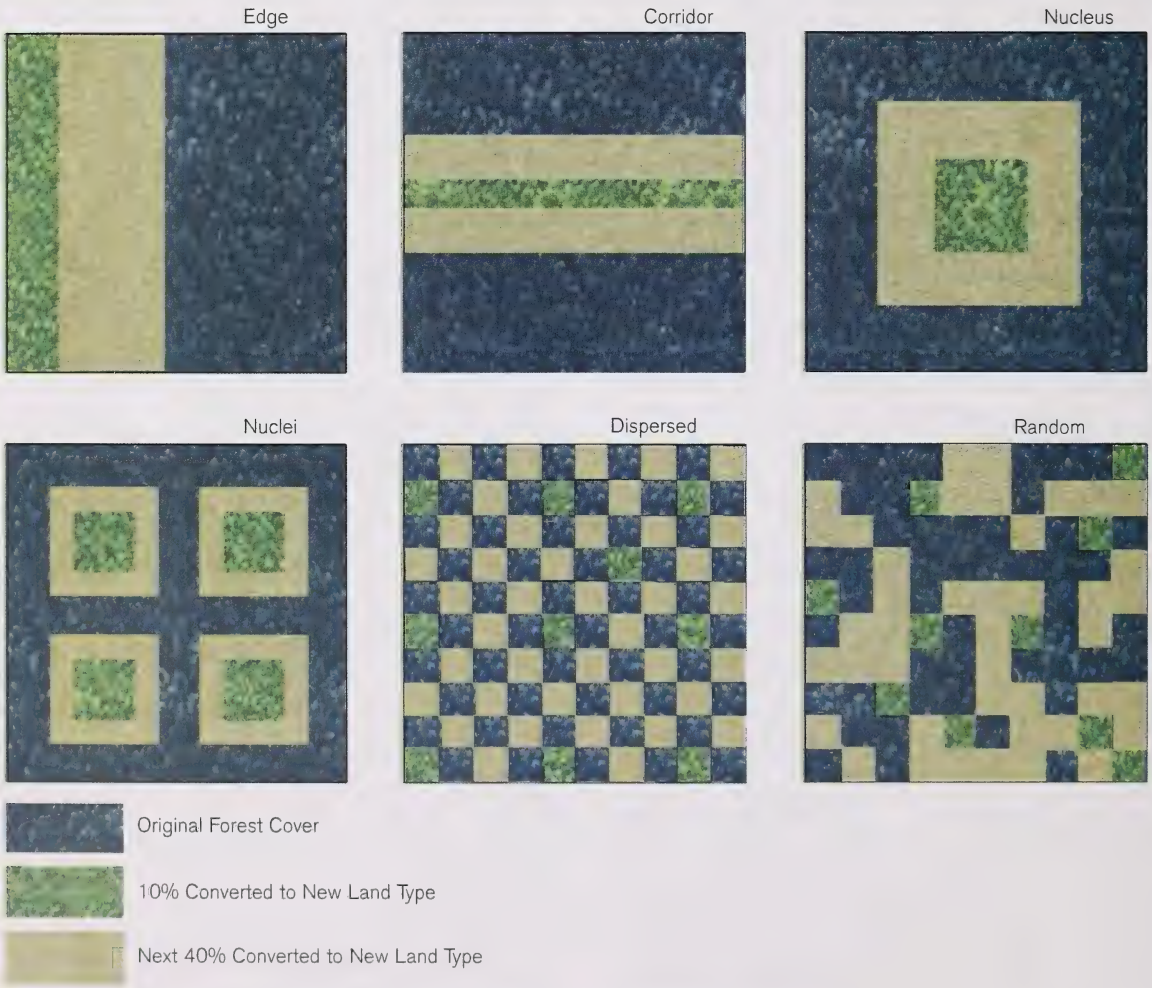


Figure 43. Conceptual Land Transformation Sequence Models (after Forman, 1995)

Photo showing a dispersed pattern of alternate patch clearcutting. The first pass has been removed and the remainder will be removed after regeneration is established. Visual impact is high and landscape fragmentation is nearly complete.

Figure 44. Dispersed Cutting Pattern

Photo indicating Alternate Patch Clearcutting with second pass removed. Note the lack of connectivity across altered landscape and long unprotected downhill runs subject to potential erosion.

Figure 45. Two Pass Dispersed or Alternate Patch Clearcutting Pattern

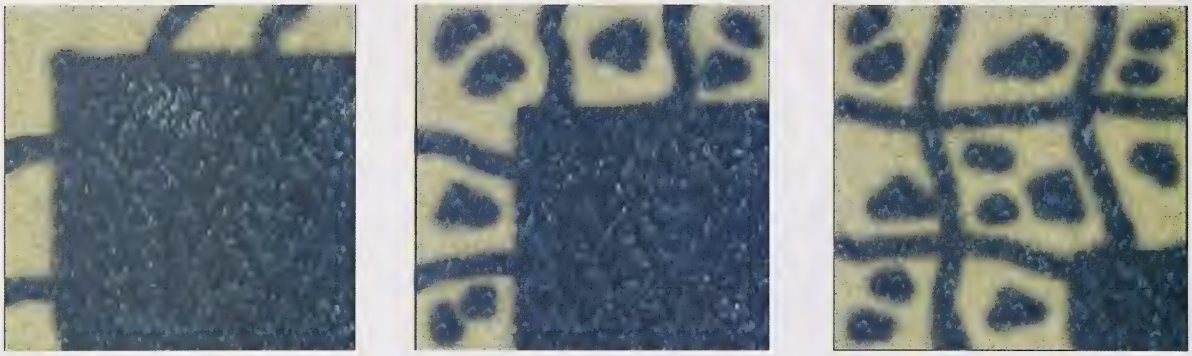
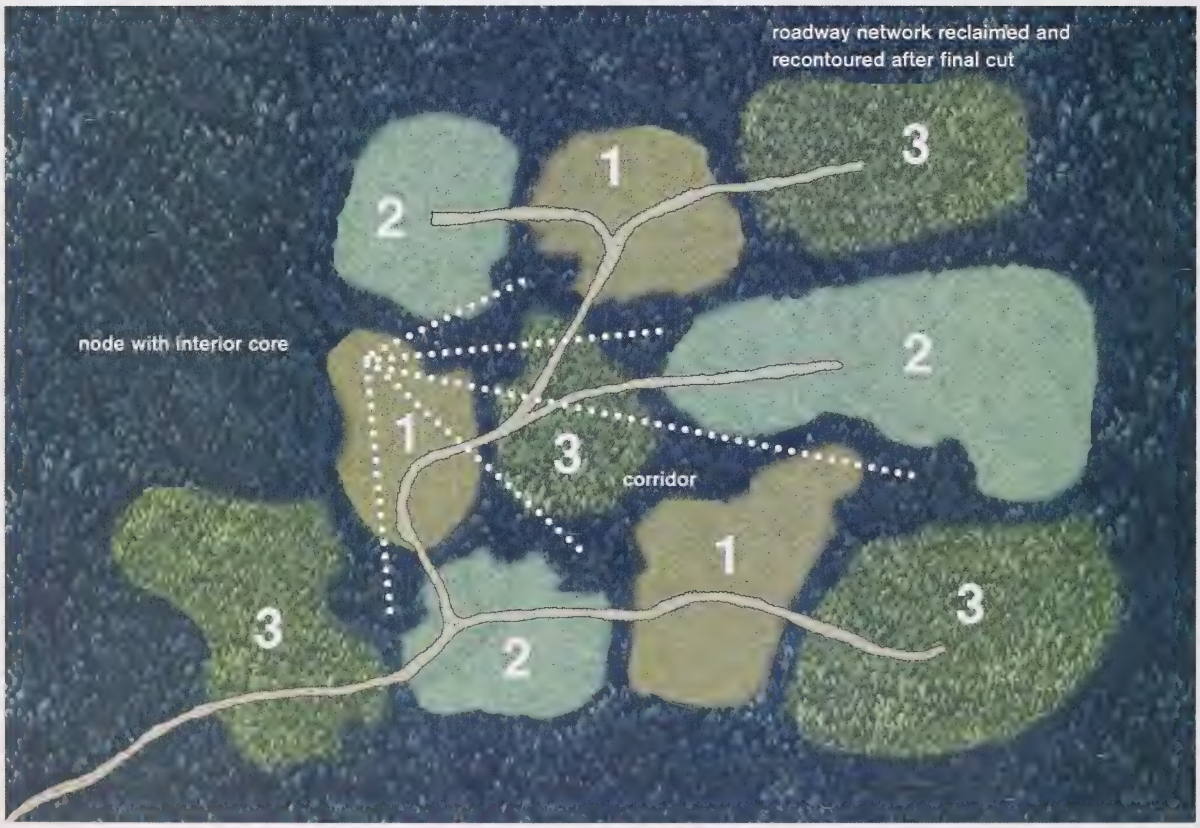


Figure 46. Jaws and Chunks (Forman, 1995) With Remnant Island Stepping Stones and Corridors



(not to scale)
1 = area of most recent cut
2 = area cut after vegetation stabilization of area 3
3 = area cut first
Large blocks approximating natural fire size may be cut in this fashion. Adjacent areas have very long return rates for cutting. Variable age rotation is possible with this system.

Figure 47. Grape Cluster Aggregate Model for Subdividing and Sequencing Very Large Cutblocks

patches and to retain those components as long as possible. Of the transformation sequences listed (edge, corridor, nucleus, nuclei, dispersed), the edge model maintains the largest patch for the longest period of time. This can be approximated with the progressive clearcut. However, certain aspects, such as connectivity and stepping stones, are not well addressed by the edge model.

Cutting in the Southern Rockies study area has traditionally been carried out in a two pass dispersed model, whereby the first 50% of the merchantable area is removed in a dispersed or alternate clearcut. The second pass in which the remaining area is removed takes place after satisfactory regeneration is achieved. Aside from riparian buffers, no real attempt is made to provide for connectivity in the uncut forest. The resultant dispersed cut pattern perforates and fragments the landscape rapidly (Figures 44 and 45). In fact, the dispersed pattern is the model to adapt if fragmentation is a management goal. Once the residual blocks are removed, extremely large cut-over patches are formed that may or may not have stepping stones or corridors across them. Frequently they do not. The dispersed model of land transformation (many small dispersed cutblocks) is ecologically inferior because of the early loss of large patches (Forman, 1995).

The following patterns should be considered as an alternative to dispersed cutting. Larger blocks than are currently cut may be considered in the area if natural or inherent disturbance regimes are to be more closely followed. As they are currently not common and the public may not be aware of their ecological value, they may face public resistance. The problems of large blocks such as negative visual quality, within block connectivity, potential erosion and water quality issues must be addressed.

5.1.1. JAWS AND CHUNKS CUTTING

Forman (1995) has put forward a method of transforming an area by progressively cutting from two sides, but at the same time allowing for corridors and stepping stones across the altered landscape (Figure 46). He refers to this as the jaws and chunks approach. Very large clearcuts may be possible with this model although some problems such as erosion may still exist.

5.1.2. GRAPE CLUSTER CUTTING

The entire area indicated, which may be as large as 1,000 ha, is considered one cutblock area and will likely be cut within 4-10 years. The sub-blocks are sequenced, not in consideration of regeneration but in terms of site stabilization. Once enough vegetation is established on the sub-block to control erosion, the next sequence of sub-blocks is cut. Once the second sequence is stabilized, the third is free to be cut. Corridors are left between the sub-blocks, and nodes large enough to provide an interior core are left at intersections in the corridor network. If sub-blocks are larger than 20 ha, some interior stepping stone islands should be provided (with or without interior cores). Where possible, sub-block boundaries follow vegetation type boundaries, roads are positioned so as to not pass through nodes. The network of corridors and nodes provides for connectivity as well as providing for a reduction in fetch (wind run) of the blocks. This should reduce evapotranspiration and potentially increase snow accumulation. While portions of the corridor and islands may blowdown, this will provide additional large woody debris which has other ecological benefits. In this way, the very large cutblocks required to approximate stand replacement fires may be accommodated while mitigating visual impact, as well as soil erosion and water quality concerns (Figure 47).

5.2. PROVIDING INTERNAL CUTBLOCK STRUCTURE

Residual internal cutblock structure may be added to any of the previously described silvicultural systems to provide the desired patch characteristics, particularly those systems that involve a high amount of tree removal. Residual internal cutblock structure may be defined as single trees, snags or groups of trees that are identified and retained for a defined period of time, or left indefinitely, to meet objectives other than natural regeneration (BC Environment, 1995). The degree to which cutblock structure is established or retained must coincide with the overall management objectives for the site. In some cases, internal structure may in fact, not be desirable. The silvicultural system should be chosen to achieve the desired management objectives.

The term "reserves" is used to modify any silvicultural system with internal residual structure (e.g., clearcut with group reserves or seed tree with uniform reserves). Outside of silvicultural considerations, structure within the cutblock serves to:

- provide a higher visual quality;
- provide a source of coarse woody debris over the long-term; and
- function as wildlife habitat and promote greater vertical and biological diversity over time.

5.2.1. GENERIC CONSIDERATIONS FOR CUTBLOCK SIZE, SHAPE AND RESIDUAL STRUCTURE

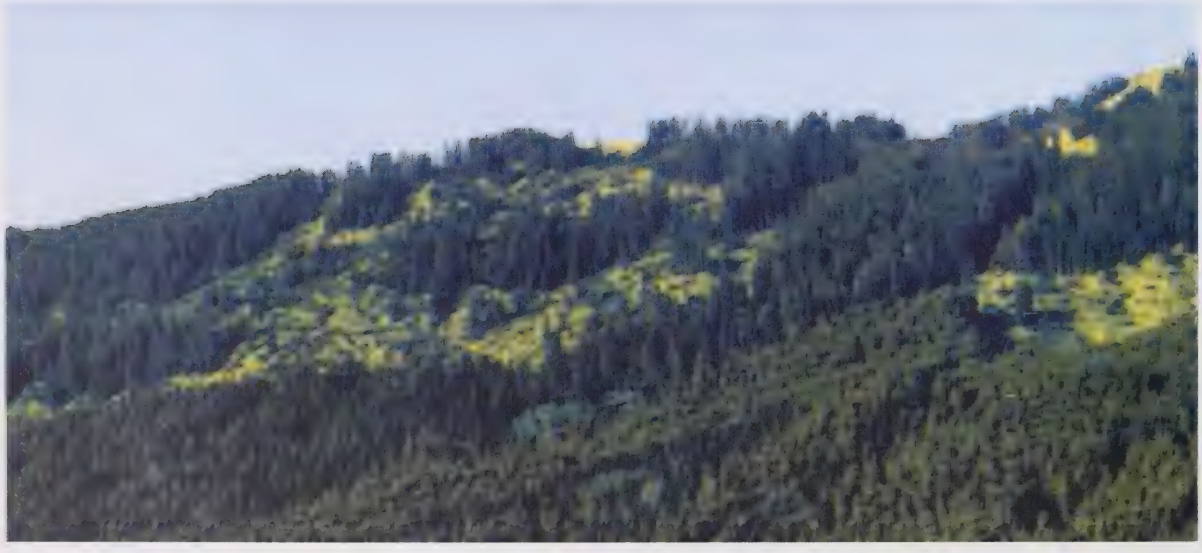
Residual cutblock structure may consist of one or more of the following elements. These elements may be uniformly distributed or concentrated in groups within the cutblock.

Cutblock size and shape

- the size and shape of the cutblock should reflect the management objectives for that block
- cutblock shape should blend into the surrounding landscape by following contours and stand type boundaries
- cutblocks should mimic the size and shape of natural disturbance patches (mountain pine beetle, burns and avalanches)
- patch shape should be monitored with a length to width ratio (L:W)
- convoluted patches have a high number of lobes, long perimeter, high L:W ratio and normally an abundant interaction with the forest matrix (Forman, 1995). These patches, unless quite large, will lack an interior core.
- a circular patch will have the lowest L:W ratio and the least interaction with the adjacent forest matrix, but will provide the largest interior area (Forman, 1995)

Residual cutblock structure or "reserves" can be added to any of the silvicultural systems and will encourage the use of the interior of the cutblock by wildlife, as well as provide an incidental seed source and protection for regeneration from extreme temperature and moisture conditions.

Figure 48. Systems With Interior Cutblock Structure (Reserves)



Note the undulating edge, residual islands, individual trees and snags. This is the result of a Pine Beetle salvage operation.

Figure 49. Cutblock With Interior Structure

Individual green trees

- make the best use of wind firm species to avoid potential blow down
- large-diameter, unmerchantable tree species should be considered first as snag recruitments

Residual islands or stepping stones

- the number and size of the residual islands should reflect the size of the cutblock, the number of passes in the harvesting system and wildlife management objectives
- some stepping stones may be built around nesting trees or snags to provide wind firmness. Although these are significant, they will not have the interior core required by some species.
- some stepping stones should be large enough to provide an interior core. E.g., Thomas, 1995, found the best cover patch size for elk was to have a minimum radius of 3 sight distances (61 m) = 183 m = 10.5 ha. The interior core of this patch would be represented by a radius of 2 interior sight distances = 122 m = 4.7 ha.
- in order for a patch to have any interior core, it must have a radius greater than 1 sight distance = 61 m = 1.2 ha. These figures must be considered approximate and require field verification for the cover type in question.

Snags

- evenly distributed, dead standing trees should be left as snags. Snag density requirements are currently unknown.
- the minimum size snag should not be less than 10 cm d.b.h. (diameter at breast height) and 6 m tall
- large, live non-commercial trees with physical defects or poor form should be left on site as snag recruitment trees

Downed Wood Debris

- scatter downed large woody debris (> 8 cm) over the block

Debris piles

- piles of woody debris may be left at an irregular spacing for use by fur-bearing mammals
- debris piles are not a natural feature of the landscape and may create some imbalances in predator/prey relationships

Feathered edges

- reduces hard edge lines, reduces predator advantage and nesting parasitism
- increase wind firmness of edge

5.3. SILVICULTURE AND WILDLIFE HABITAT MANAGEMENT

Large-scale wildlife habitat management must be accomplished through timber management. Timber management affects large areas, dramatically affects wildlife habitat, has great impact on wildlife and is well financed (Thomas., 1979 p. 13).

Forests must be managed to provide necessary wildlife habitat conditions along with a sustainable and relatively even flow of wood products. In order to simultaneously achieve biodiversity, specific wildlife habitat and timber management objectives, numerous variables may be manipulated at several scales. At the broader regional and landscape scales, key patterns and processes must be maintained if biological diversity and essential elements are to be conserved. The desired future landscape patterns should be the result of an integrated assessment of historical and existing landscape conditions as well as considerable stakeholder consultation. Several approaches to the conservation of biological diversity and wildlife habitat are required including both coarse and fine filter approaches. Coarse filter approaches refer to the retention of essential broad scale landscape patterns and processes (refer to Section 5.1.) including diversity of vegetation types, maintenance of age class structure within the range of natural variability, connectivity of the landscape, etc.

Silviculture can contribute to the coarse filter approach when management interventions are considered in aggregate. However, the following sections deal with more detailed approaches. Silvicultural systems tend to be a tool in the fine filter category which includes the maintenance of habitat for single wildlife species of specific concern. It is difficult to manage habitat for a set of specific species because of their divergent needs. Forest management activities can have a positive, neutral or negative impact on specific wildlife species. What is a positive treatment for one group of species may be negative for another. Nevertheless, specific species requirements may need to be considered. In addition, wherever rare, unique or special elements exist, managers should consider and formulate unique management strategies that are specific to the sites in question (e.g., calving areas, denning sites, rare ecosystems).

Also, one of the most important factors for the management of large predator and ungulate species is the road network. Access by humans should be managed to reduce harassment and hunting pressure.

Silvicultural system and harvesting method

The selection of a silvicultural system and harvesting method will influence the amount and distribution of interior cutblock structure after harvesting. The forest manager must consider the types of habitats which are adjacent to areas being harvested in order to evaluate the effectiveness of the habitat elements within the cutblock.

Size and shape of the area to be harvested

The size and shape of the cutblock will influence the operating costs of the harvesting operation and the use of the opening by wildlife. In general, smaller cut units require more roads for access, but may achieve

a higher level of use by wildlife in the stands themselves. However, the small size may result in fragmentation of the matrix and other negative off site impacts.

Stand condition

Stand condition refers to the present health of the stand, the species composition and the vertical and horizontal structure.

Spatial and temporal arrangement of stand types

The spatial and temporal arrangement of stand types across the landscape can be achieved through the use of various silvicultural systems. The juxtaposition of habitat types is very important for animals that require two or more habitat types. The broader scale cut sequence must be considered when prescribing silvicultural treatments.

Access Requirements

Accessibility of the road system is one of the most important variables affecting wildlife. Far ranging wary carnivores are particularly susceptible to increased access. Managers need to consider the importance of the timing and extent of access into an area when selecting a silvicultural system.

5.3.1 SILVICULTURAL GUIDELINES FOR SELECTED WILDLIFE SPECIES

Habitat is a key element to successful wildlife management. In addition to a coarse scale approach, foresters must understand the habitat requirements of specific wildlife species of interest. The following examples of specific requirements are neither exclusive nor prescriptive, but are provided as examples of the type of considerations that might be incorporated into stand and landscape level silvicultural solutions. Dependent on the area, other species may need to be addressed.

The following are brief summaries and design recommendations for wildlife species of particular interest in the study area. The forest management guidelines for these species should be considered in the harvest design, layout and implementation of silvicultural systems in those areas where habitat improvement or retention is considered important. Details of individual species requirements, models and map outputs of potential habitats have been completed for the area and are available through the Southern Rockies Landscape Planning Pilot Study.

5.3.1.1. GRIZZLY BEAR

Food requirements

- grasses, sedge, forbs and roots grown in moist swales or depressions (spring to early summer)
- berry producing shrubs (late summer to fall)

Cover requirements

- uncut forest
- riparian corridors
- dense tall shrubs

Grizzly use of clearcuts

- moist swales and depressions – *best*
- slash broadcast burned (improved plant growth) – *moderate*
- slash dozer piled – *poor*
- opening life of clearcuts as food supply for the grizzly is from 4 years after cut to approximately 30 years dependent on site conditions
- decaying wood debris and stumps that are being consumed by beetle larvae and carpenter ants are beneficial structures as they provide a food source for the grizzly

Forest management guidelines for grizzly bear

- clearcuts should be designed to provide escape cover for the grizzly. Hiding cover is important in avoiding human harassment and for protecting sows and their cubs from male grizzlies. One study indicated that 82% of grizzlies using cut-overs were within 50 m of cover (Zager, 1980). Escape cover does not have to be high forest, but may be shrubs. Long narrow cutblocks or those with many island remnants may accommodate this requirement.
- shelterwood cutting will maintain continuous high forest cover, which is one habitat component needed by the grizzly
- small clearcuts (less than 12 ha) in low, dense, subalpine fir depressional sites may create the grass-forb swales useful to the grizzly bear in spring and early summer
- commercial thinning and/or group selection in western larch or lodgepole pine stands may create favourable conditions for berry producing shrubs (huckleberry, saskatoon, etc.)
- retain old growth forest between habitat components and within riparian corridors (old stumps and dead wood within the old growth forests are a source for grubs and insects, cover and denning opportunities)
- fallen logs and stumps that are being consumed by beetle larvae or ants should be maintained in the cutblock. The insects are a food source and encourage use of the block by grizzly bears. Ensure monitoring for potential spruce beetle problems in fresh, downed spruce slash (the preferred host of the spruce beetle).
- the timing and proximity of the timber operation may be disturbing to the grizzly bear. If grizzly are known to be in an area, consider shutting down the operation until they have moved out of the area.
- although strictly beyond silviculture, road layout and access management are critical to habitat effectiveness of the area
- other factors apply – refer to grizzly model (Alberta Environment, 2000) for additional information

5.3.1.2. ELK

Habitat requirements

- primary winter range occurs on snow free or low snow slopes adjacent to good quality thermal cover
- critical winter range is the portion of primary winter range occurring on:
  - gentle slopes (10-20%);
  - south to west aspects; warm dry ecosites (lower elevations); and
  - abundance of palatable browse species.
- in a general sense, optimum summer range habitat is an interspersion of 40% cover and 60% forage where water is no further than 800 m (Mackie, 1970)
- other factors apply – refer elk habitat model (Alberta Environment, 2000) for additional information

Habitat factors

- hiding cover consists of dense, high forest with understory shrubs and low branching (Black et. al., 1976). Hiding cover exists when 90% or more of a standing deer or elk is hidden at a distance of 61 m (Thomas, 1979).
- the best cover patch size for elk has a radius of at least 3 sight distances. A sight distance is that distance where 90% of the animal is hidden from view, which by the definition is 61 m. Therefore, the best cover patch would have a radius of 183 m which occupies a total area of 10.5 ha (Thomas, 1979).
- thermal cover requires a minimum of 4 m in height with a crown closure of at least 70%
- travel lanes should be of sufficient size to function as hiding cover. This does not have to be continuous cover, it may be composed of non-continuous patches separated by openings of less than 90 m (Thomas, 1979).

Forest management guidelines for elk

- clearcut openings should not exceed 366 m across (or 183 m from the edge) without residual islands for hiding and thermal cover. Travel lanes for movement through larger cutblocks should be considered in a larger single pass, timber harvesting operation. Design travel lanes in areas with the least topographic resistance to movement for the deer or elk.
- residual islands within larger clearcut blocks should be 10 ha in size to promote effective cover
- partial cuttings that leave high forest cover can maintain the cover requirement for elk. Maintain basal areas of 14-21 m^2/ha with a density of 150-225 stems/ha (Lyons, J., 1980).
- elk consistently move away from active logging operations; however, the distance travelled is varied. Operations along ridge lines, where men and equipment are visible and sound can travel the furthest, cause the greatest movement and the most negative response. (Lyons,1979).
- confine timber operations to a single drainage as disturbance to deer and elk seems to be tempered by ridge lines (Lyons, 1975, Ward, 1976). The elk will retreat to the adjacent drainage, assuming it has the appropriate interspersion of habitat types.
- keep straight line distances less than 400 m when laying out cutblocks or roads. An undulating feathered edge is best. Slash piles within the cutblock will break up the line of sight (Montana Cooperative Elk–Logging Study, 1975).
- logging slash or downed woody debris deeper than 2 feet decreases use by deer and elk in both timber stands and clearcuts (Lyons, 1975)
- roads reduce the effectiveness of cover areas and disturb elk. Openings such as meadows, clearcuts and other foraging areas should be screened from main roads using buffers or topography. Roadside buffers should be a minimum of two sight distances or 122 m (Ward, 1976).
- roads should be laid out to facilitate closure with gates, which may be necessary to protect deer or elk from harassment (Coggins, 1976)
- roads should be minimized through deer and elk travel routes. Minimize right-of-way clearings and distances when crossing through these areas (Montana Cooperative Elk–Logging Study, 1975).
- impact on elk habitat, from the construction of new roads, would be reduced if roads were located in dense forests (providing hiding cover) and on east facing slopes (less frequented by the elk) (Ward, 1976)
- elk are known to calf in the same area year after year. These areas should be avoided for timber harvesting and access should be closed during the spring calving season to avoid harassment.

5.3.1.3. MOOSE

Habitat requirements

- on a landscape level, the best overall habitat has a diversity in cover patch types and variable age classes, plus an interspersion of openings and dense conifer
- summer range consists of:
  - cool, moist riparian zones;
  - dense thermal cover (cool);
  - moist sites with lush terrestrial and aquatic vegetation (diversity of forage); and
  - mineral licks.
- in a study done by Jim Peek in the boreal forest of Minnesota, the optimum interspersion pattern of habitat components consisted of:
  - early successional forest stands (40-50% of area);
  - old growth or mature spruce/fir (15%); and
  - aspen stands and aquatics (35-40%).
- fall feeding consists of:
  - residual leaves of trees and shrubs (especially willow); and
  - heavy intake of fallen aspen leaves.
- winter feeding consists of:
  - current years growth (lower nutrient levels than summer food) – Salix, Betula, Populus, Cornus, Prunus and Amelanchier; and
  - in extremely cold weather, forage may occur on fir.
- winter bedding sites consist of dense thermal cover consisting of:
  - heavy balsam or subalpine fir stands;
  - tree heights greater than 15 meters tall; and
  - a canopy closure greater than 75% (Timmermann and McNicol, 1988).

- mature and old growth spruce/fir become most important during the late winter and early spring when moose fat and energy reserves are depleted. During this time, moose select these stands for:
  - snow interception;
  - warmer microsites;
  - non-crusted snow;
  - hiding cover; and
  - thermal cover.

Forest management guidelines for moose

- the optimum clearcut size and shape should not exceed 30 ha in a narrow elongate or convoluted pattern. Maximum width of the cutblock should not exceed 160 m. Contour the cutblock to blend into the surrounding landscape (Timmermann and McNicol, 1988).
- the maximum size clearcut, for the benefit of moose, may be up to 100 ha in size, but residual treed islands within the block for browse and cover become essential (especially for cow/calf pairs). The maximum distance between effective cover patches should not exceed 160 m (Timmermann and McNicol, 1988).
- regeneration in adjacent cutblocks should be at least 6 m in height (preferably 15 m) before a new clearcut is started (Timmermann and McNicol, 1988).

5.3.1.4. BARRED OWL

Habitat requirements

- the barred owl is a secondary cavity nester found in dense, dark mixedwood or coniferous forests, especially those located near lakes, streams, swamps or marshes (Godfrey, 1986). They may also nest in deserted nests of hawks or crows (Godfrey, 1986).
- the barred owls prefer large woods and require stands that are sufficiently mature to provide numerous nesting and roosting hollows (Craighead, 1969)

Forest management guidelines for the barred owl

- an important element in managing habitat for the barred owl is to ensure the long-term health of the riparian zones and reserve stands
- maintain residual islands and snags within clearcuts
- maintain old growth stands adjacent to cutblocks
- clearcuts with feathered edges may reduce the predatory advantage created by artificial, straight lines of some cutblocks

5.3.1.5. PILEATED WOODPECKER

Habitat requirements

- the optimum habitat for the pileated woodpecker is roughly synonymous with old-growth forest. Old-growth forest provides the habitat structure necessary for both nesting and feeding (Bull, 1975).
- suitable nesting trees for the pileated woodpecker are dead trees (snags) with heart rot, that must be more than 50.8 cm in diameter at breast height (Bull, 1975). This may be less in the C5 management unit.
- the preferred nesting areas are uneven-aged stands with a crown closure of approximately 70% (Bull, 1975)
- the primary food source of the pileated woodpecker are carpenter ants and their larvae which are found in trees with heart rot (Bull, 1975). Another source of food for the woodpecker are bark beetles and their larvae, which may be found under the bark of mature pine or spruce trees.

Forest management guidelines for the pileated woodpecker

- the territorial requirement of the pileated woodpecker is approximately 120 ha, therefore, stand sizes should be a multiple of that number in order to maximize the population density and utility of the area for the woodpecker (Thomas, 1979)
- where old-growth stands already exist, the stand should be managed using a light selective silvicultural system to maintain the uneven-aged structure, with a 70% crown closure. This could be combined with an active snag management program.
- snag management considerations for the pileated woodpecker:
  - at the maximum potential population density for the pileated woodpecker, in a mixed conifer community, the snag requirement would be 1 snag per 3 ha (Thomas, 1979, p. 150). This includes snags within riparian and reserve areas;
  - the rotation of the forest must be long enough that the stand condition begins to decline in order for snags to develop;
  - old, non-commercial trees with physical defects or poor form should be left as snag recruitment trees;
  - snags may be created by killing (girdling) select trees or by controlled burning;
  - an even distribution of snags is important because of the territorial nature of the pileated woodpecker; and
  - snags benefit a wide range of animals, other woodpeckers and owls, (i.e., invertebrates, top-dwelling birds, and cavity-dwelling mammals like bats, squirrels and marten).
- starting from a new clearcut, a 240-year rotation may be required to establish the old growth condition required as suitable habitat for the pileated woodpecker. The first 120 years would have to be managed intensively. Precommercial and commercial thinnings would have to be conducted in order to promote a rapid growth in tree diameter. At 120 years, the stand will begin to stagnate and some trees will begin to transform into snags. At 160 years, the appropriate old-growth stand condition should exist as suitable habitat for the pileated woodpecker (Thomas, 1979). From this point, the stand may be managed as an uneven-aged stand.

5.3.1.6. MARTEN

Habitat requirements:

- martens prefer mature conifer or mixedwood forests with snags and fallen logs for habitat components. An uneven-aged stand offers a diversity of tree sizes and age classes to provide hunting sites and cover. Mixed age stands may support more prey species for the marten (Hargis and McCullough, 1984).

- marten may tolerate a variety of forest habitats if food and cover are available. Berries, mice and voles are a major component of their diet.
- bogs and riparian areas form a significant component to the martens' habitat requirements

Forest management considerations for the marten

- extensive clearcuts and large fires will severely reduce habitat value for martens for as many as 15 years (Clark, 1975)
- small clearcuts (8-12 ha) with snags, debris piles and a slash loading of approximately 35 tons/ha within the cutblock may be acceptable habitat for the marten. Suitable high forest cover must be left surrounding the cut (Hurrell, 1968).
- larger clearcuts will require residual islands for cover and hunting structure
- at least 25% of the total area being managed must be retained in high forest cover with basal areas of at least 25 m^2/ha of pole size or larger spruce, pine and fir (Soutiere, 1979). This may be achieved by selection harvest.
- riparian zones are critical to the marten. Uncut strips, at least 100 m wide, should be left along waterways (Snyder, 1984).

5.3.1.7. MINK

Habitat requirements

- mink occupy a variety of riparian wetland habitats including streams, rivers, lakes, bogs and marshes where there is an abundance of prey
- log jams may be an important habitat element for the mink during the deep snow conditions of winter (Grinnell, 1937)

Forest management guidelines for mink

- the key to managing mink is to manage the health of riparian zones and to keep log jams along the streams
- a riparian zone should be defined, on the ground, on the basis of its complete function to the stream which it protects, not just on the basis of a buffer width (refer to Stream Influence Zones)
- selective hand logging within the riparian zones will help to promote wind firmness of trees and long-term health of the riparian zones, although this may reduce the number of log falls into the stream which may be considered as beneficial

5.4. SILVICULTURE AND VISUAL RESOURCE MANAGEMENT

The consideration of scenic values and the incorporation of visual resource management into forest planning processes is receiving greater emphasis. Silviculture has the potential to profoundly alter the visual character and value of both individual sites and entire landscapes if operations are undertaken without careful consideration of the scenic integrity of the area. Visual resource objectives need to be considered during the setting of objectives for the area as well as during the establishment of the target stand structure.

Silvicultural systems may be used to both improve scenic quality as well as to mitigate the effects of interventions into natural landscapes. The process of inventory, analysis and development of landscape character goals and scenic integrity objectives is complex and cannot be given sufficient treatment in this report. The details of visual resource management in forested landscapes are well covered in other handbooks (U.S.D.A., 1995).

The design process is not simply a matter of selecting an appropriate system to hide operations. The process involves the identification of the essential landscape character, overall scenic integrity, visibility analysis, distance zone delineation and prescriptions for appropriate types, forms, configurations and extent of forestry operations. The process is both scientific and artistic.

The ecological inventory used to identify appropriate treatment systems may also be used to map the visual landscape. Preference surveys may be undertaken based upon an ecological land classification. Visual preference varies among individuals and it is prudent to conduct a visual preference survey specific to the region and landscape under consideration.

Studies have indicated that rectilinear clearcuts in otherwise unmodified landscapes tend to drastically reduce the visual preference for an area (Alberta Environment, 2000). Various types of silvicultural systems may be used in areas of very high visual value. Shelterwood systems, commercial thinnings and selection harvesting may be necessary in areas that are nearby, visually sensitive, highly preferred and highly visible. However, visual resource management is not exclusively about hiding forestry operations. It is the integration of aesthetics and scenery into forest management and cutblock design. Highly visible clearcutting may in fact be designed in such a way as to be pleasing and aesthetically attractive.

Prescriptions for silvicultural systems that respond to the visual character of the landscape are usually place specific and require individual solutions. The ability of different landscapes to absorb forest interventions is highly variable and designs usually must be tailored to the specific and inherent visual character of the place. The range of silvicultural systems outlined in this report, together with ecologically based visual preference studies, provide powerful tools with which to manage the visual landscape.

Definitions

Clearcut is an area of forest land from which all merchantable trees have been removed in a single regeneration cut or single stand entry.

Coppice system is defined as a deciduous, even-aged silvicultural system for which the primary regeneration method of trees is vegetative sprouting of either suckers (originating from existing root systems of cut trees) or shoots (originating from the cut stump).

Debris piles are piles of woody debris, left at irregular spacing across a cutblock, for use by fur-bearing mammals.

Downed woody debris is wood debris or slash (> 8 cm) that is scattered over the cutblock.

Establishment treatments refer to treatments of the stand and site during the establishment of regeneration.

An **even-aged silvicultural system** will produce generally even-aged stands.

An **extraction** method is the process by which the regeneration cutting is completed. This includes the falling, skidding, landing, loading and hauling of wood fibre from the logging site to the mill. Consideration must also include limbing, topping and debris disposal.

Feathered edges is a partial cut edge of a cutblock that reduces the hard line transition from a clearcut block to an adjacent reserve stand.

Final cutting is the last cut made on the site which completely uncovers the regeneration. The first removal cutting may actually be the final cutting.

The **group shelterwood system** involves a series of partial cuts applied in a pattern of expanding groups or patches.

Group tree selection is defined as a silvicultural system that removes trees in small defined groups or strips, called regeneration openings, to perpetuate an uneven-aged stand condition.

High grading is a type of partial cutting that removes only certain species above a certain size or of a high value. Known silvicultural requirements and/or sustained yields are wholly or largely ignored.

Horizontal stand structure refers to the diversity of structure across any given forest stand.

The **irregular shelterwood system** involves leaving the residual trees for long periods beyond the regeneration phase. Over this extended period of time, the residual trees will initiate new age classes of regeneration.

Landscape is a heterogenous land mosaic "where the mix of local ecosystems is repeated in a similar form over a kilometers wide area" (Forman, 1995).

The **natural shelterwood stands** have a well established understory of shade-tolerant trees.

The **nurse-tree shelterwood system** allows for the management of a shade-intolerant overstory with a shade-tolerant understory on the same site for a certain period of time.

Old-growth forest is a forest stand older than 150 years. It may or may not be in decline. The structure and age of an old-growth stand will vary depending on the forest region, habitat type and health of the stand.

The **patch cut** is a miniature version of the clearcut not greater than 1 hectare in size.

Preparatory cut is a partial cut done several years prior to a seed tree harvest in order to promote wind firmness, health and vigour of the remaining trees in the stand.

Prescribed burning involves the controlled use of fire to maintain or control vegetation.

Pruning involves the removal of limbs to improve wood quality and alter microclimate for shade-intolerant regeneration.

Reforestation is the renewal of a forest crop by natural or artificial means.

Regeneration cutting involves opening up enough vacant growing space in a single operation to allow the establishment of new regeneration.

Release treatment involves freeing young crop trees from competition.

Cleaning: removing overtopping competitors of the same age.

Liberation: removing overtopping competitors of an older age.

Weeding: removing any competitor, regardless of position.

Removal cutting gradually uncovers the new crop of trees while making the best use of the overstory's growth potential.

Residual cutblock structure may be defined as single trees, snags or groups of trees that are identified and retained for a defined period of time, or left indefinitely, to meet objectives other than natural regeneration.

Residual islands or stepping stones is a patch of timber that is left standing within a cutblock.

Riparian areas are areas which are influenced by the subsurface hydrology (high moisture) associated with streams, rivers and wetlands, as well as the adjacent upland vegetation that exerts an influence on it.

Salvage cutting involves the removal of dead trees while still marketable.

Sanitation cutting or operation involves the removal of timber damaged by a natural disturbance such as fire, insects, disease or storm winds.

The **seed tree method** is defined as a silvicultural system in which selected trees or groups of trees are left standing after the initial harvest to provide a seed source for natural regeneration.

The **shelterwood system** is defined as a silvicultural system in which mature trees are removed in a series of cuttings to achieve a new even-aged stand under the protection or shelter of the remaining trees.

Silviculture is the theory and practice of controlling forest establishment, structure, composition and growth, based on sound ecological principals and forest management objectives.

A **silvicultural system** includes one or more regeneration cuttings (harvesting of older trees for the purpose of bringing about new regeneration) and any other silvicultural treatment of the forest stand over the entire length of the rotation.

The **single tree selection system** is defined as an uneven-aged silvicultural system in which new age classes are created by the removal of older individual trees somewhat uniformly throughout the stand.

Site preparation involves the removal of debris and/or competition to improve the growing conditions for the new seedlings: may be done mechanically, manually, chemically or by prescribed fire.

Snag is a standing dead tree not less than 10 cm d.b.h. (diameter at breast height) and 6 m tall.

Stand tending or maintenance treatments refer to any stand treatment, at times other than regeneration, during the length of the rotation.

The **strip shelterwood system** involves a series of linear strip cuttings that advance progressively across the cutting area.

Thinning reduces the number of stems per hectare to increase growth and improve health and vigour of remaining crop trees.

An **uneven-aged silvicultural system** will produce stands with at least three well represented age classes.

The **uniform shelterwood system** involves a series of regeneration cuts with an even distribution of leave trees, in sufficient number, to provide the appropriate microsite conditions for the new crop of trees.

Vertical stand structure refers to the aerial, surface and subsurface layers within a forest stand.

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